The Dock and Harbour Authority

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Editorial Comments

The Port of Monrovia.

The Republic of Liberia was founded in 1822 when a settlement was made at Monrovia (named after the American President, James Monroe), by negro slaves freed from the United States, with the assistance of American colonization societies. The country was declared a republic on July 26th, 1847, and in 1948 it was decided to celebrate the 101st anniversary of its independence by opening the new harbour at Monrovia.

The port is situated about 6 degrees north of the Equator and is subject to malaria, yellow fever, sleeping sickness and other discomforts usually associated with tropical climates. For five months of the year there is torrential rain, and for the other seven, the weather is hot and dry; there is often not a cloud in the sky for weeks at a time, and land breezes carry fine red dust from the Sahara, which lies many miles to the east. During the rainy season, an average of 180-in. falls, and while the construction work of the new port was naturally impeded at this time, it was never halted altogether, and in spite of these adverse conditions, sickness among the personnel was gratifyingly low owing to the high standard of sanitation maintained on the project, and the employment of an expert on tropical maladies as contract surgeon.

The economic importance of Liberia was realised during the recent war, when it became the source of a large percentage of the natural rubber imported by the United States. The Firestone Plantations Company now has approximately a million acres of rubber trees under cultivation, and employs about 25,000 Liberians. The Republic is also rich in other raw materials such as gold, timber and iron ore.

The leading article in this issue, describes the port and harbour of Monrovia, which is a good example of a port built upon the open sea and on undeveloped land. The design and construction have several items of particular interest; the two breakwaters are works of a major character, and the plant and tools used in quarrying the unusually hard basaltic rock with which they were built, indicate the difficulties which attended this work.

In connection with the wharf, it will be noted that steel joist piles were used, the upper portions being protected with a bitumastic covering. One would have expected to see reinforced concrete piles adopted, particularly in view of the fact that the heavy steel piles had to be transported across the Atlantic. In respect to quayside equipment, all transhipment of cargo is carried out by ships' gear, and no cranes are provided except for heavy lifts. Special ore cranes are being erected at one end of the wharf, where storage and loading facilities have been arranged for over a million tons of iron ore per annum.

The development of the iron deposits, located forty miles from the port in the Bomi Hills is still in its infancy, but the export of high-grade ore to the United States appears likely to become of great importance.

Owing to the anticipated progressive increase in shipping using Monrovia, the lighting of the coastal waters is of some concern, and it is interesting to note that the new lighthouse installations at Monrovia and Cape Palmas have been equipped with modern electrically-operated lights by a British firm.

The first few years working of the new port appear to have been markedly successful, and the development of Liberia and the continued expansion for mutual benefit of the resources of that country are objects which, in these days, are of particular significance in world economics and politics.

The Joint Engineering Conference 1951.

We are printing in this issue a synopsis of some papers on maritime and marine engineering subjects which were presented at the Festival of Britain Engineering Conference. The full programme of subjects covered every branch of civil, mechanical and electrical engineering and included aviation, telecommunication, television, public health and education.

The theme of the conference was the contribution made to civilization by engineers and scientists during the past 100 years while, in the discussion which followed the presentation of each paper, the emphasis was on the future trends of engineering science and the growing interdependence of all branches of engineering.

The meetings were well attended by representatives from the Dominions and Colonies, and from the United States and Western European, Engineering Institutions and Societies. Arrangements have been made for the papers and the discussions to be published in eleven parts divided into subjects, and the section which will be of chief interest to readers of this Journal is Part 3, "Sea Transport." Copies are available at the price of 7s. 6d. to members and 8s. 6d. to non-members, or alternatively, copies of the entire proceedings can be obtained for the price of £3 and £3 10s. respectively.

The importance and value of the dissemination of all forms of engineering and scientific knowledge needs no emphasis, and it is encouraging that, in recent years, considerable advances have been made internationally in improving the relationship between professional engineers. We agree with the views expressed by the Institution of Civil Engineers that steps for closer international collaboration should be made by independent organizations rather than under governmental auspices, that is to say, they should be entirely uninfluenced by any political expediencies.

One further point which should be mentioned, concerns the technical education and practical training of engineers, which has been so ably dealt with in four papers at the Conference. Here,

Editorial Comments—continued

of course, much depends upon the natural bent of the individual in coming to a decision as to which branch of civil engineering he wishes to follow, but in any case, he should possess a basic knowledge of mechanical and electrical engineering. The Institution of Civil Engineers lays great stress upon the possession, by candidates for Associate Membership, of personal experience in actual construction of works. It is an additional advantage for a candidate to have some practical training in the use of workshop tools, actual drawing office practice, and the design of structures.

The modernisation of engineering colleges, and the close link between technical schools and industry, provide a sound basis upon which technical education can be built, and the present conditions governing entry into the civil engineering profession have gone a great way in assisting promising young men, who might formerly have been excluded, to obtain full qualifications.

European Mission to Study Fire Prevention.

Readers will remember that, from time to time, the dangers of dock and warehouse fires, and the necessity to organise efficient fire prevention methods, have been given prominence in this Journal. An appreciation of the international importance of the subject is becoming more and more apparent, as is shown by the fact that towards the end of last month, fire prevention experts from nine European countries arrived on a two-week visit to the United Kingdom. Their visit forms the first part of a tour sponsored by the Organisation for European Economic Co-operation.

Arrangements for the visit have been made by the Department for Scientific and Industrial Research, and the mission will spend most of its time studying recent research, carried out by British scientists, into fire prevention methods. It will also visit the Fire Service College at Dorking, and rural and urban fire stations to see the latest methods employed by firemen. The visitors will hear about the fire protection advice given to the public, and will see a demonstration of modern fire extinguishing appliances

Following their visit to Great Britain, the team will continue its Europeon tour by visiting France, the Netherlands, Western Germany, Switzerland and Italy, and at the conclusion of their itinerary, the members will prepare a report which will be circulated to all countries who are members of the O.E.E.C. organisation.

New Pest Control Order for Shipping.

Another subject of international importance is that concerning pest control on ships, and in this connection, the Ministry of Agriculture and Fisheries of the United Kingdom, and the Department of Agriculture for Scotland, recently announced that an order entitled "Prevention of Damage by Pests (Application to Shipping) Order, 1951," has been made.

The new order, which comes into operation on the 1st October next, so that all those concerned may have time to take such steps as may be appropriate to comply with its requirements, does not disturb the procedure for the control of rats and mice in foreign going vessels under the International Sanitary Convention of 1926. In relation to coastwise or other sea-going vessels which do not hold an International Deratisation Certificate or Deratisation Exemption Certificate under the terms of that Convention, a new Rodent Control Certificate is introduced in connection with the Order. The terms of this Certificate will provide that the master of such a sea-going ship for which no International Certificate is held may apply to a Port Health Authority for a Rodent Control Certificate certifying that the ship is so far as practicable free from rats and mice.

As to other vessels and craft (for example, lighters, pleasure craft, tugs and canal boats) the presence of rats and mice in substantial numbers must be reported to the Local or Port Health Authority for the port or place in which the vessel is lying. The Authority may inspect the vessel at any time, and require action to be taken for destroying rats and mice on board.

In regard to sea-going ships, a Memorandum of Arrangements applying a reasonable and practicable procedure is in course of negotiation with the appropriate shipping organisation, designed to ensure smooth working with minimum interference with shipping programmes and port working. In the case of non-seagoing vessels, i.e. craft operating within inland waterways, harbours and estuarial waters, proper notification of vessels infested with insetcs is provided for, so that steps may be taken to ascertain what action may be necessary to deal with the infestation. In certain circumstances, exemption from notification may be obtained provided disinfestation facilities are maintained and undertakings are given that any infestation will be dealt with before vessels are used for carrying or storing food.

Report on Hudson Bay Marine Insurance.

The Commonwealth Shipping Committee have again considered the question of marine insurance rates on vessels entering Hudson Bay, and their Report, the tenth on this subject, and the first since 1939, was published last week.

The latest report, which shows an encouraging increase in the number of vessels using the route, says that, since 1939, aids to navigation and knowledge of conditions on the route have much improved. The use of the Gyro compass, which is not subject to magnetic variations, has become general, and radar has been proved capable of revealing shore lines, other shipping, ice formations above the surface, and floating objects. In addition, existing aids (visual, sound and radio) have been maintained and improved.

The Canadian Government vessels have continued to contribute valuable assistance, and between 1931, when the route first opened, and the end of the 1950 season 147 ocean-going vessels have loaded and sailed from Port Churchill. The post-war figure of 76 vessels shows that the traffic using the port has increased, and in fact the 1950 figure of 20 vessels is the highest ever attained. It is noteworthy that throughout the entire period of use, only two vessels have been lost and these losses occurred in 1932 and 1936.

The evidence the Committee have collected about conditions in the Hudson Strait and Bay during the 1950 season of navigation has, as on former occasions, been brought to the notice of the Underwriters to assist them in their review of the position for the present year. Also the evidence collected from some of the masters trading to Port Churchill during the 1950 season of navigation is recorded in an Appendix to the Report.

At the request of the Committee, the Canadian Government have given consideration to a number of recommendations made by those masters, and as a result, on May 26, 1951, the Committee were informed that two new Canadian Hydrographic Charts, for Hudson Bay and Strait, and Hudson Strait have been published, and copies will be issued free of charge, to approved users. In addition, the Royal Canadian Air Force has requested Officers commanding stations from which flights are made over Hudson Bay and Strait, to instruct Captains of all aircraft flying in these areas to report the position of ice fields and ice pack.

Plans to Modernise Burmese Ports.

It has been reported that under an extensive rehabilitation programme the Burmese ports of Akyab, Bassein, Mergui, Maulmain and Tavoy are to be rebuilt and modernised and the Burmese Government have requested the Economic Commission of Asia to supply financial assistance to enable the work to be put in hand. The difficulty however will be to obtain the special equipment needed to carry out the programme which depends entirely upon the availability of supplies.

Work on the rebuilding of Rangoon, for which a million dollars (about £350,000) in E.C.A. funds was voted in February last, is now well in hand, but even when completed, the port will not be able to cope with the increased volume of trade which is expected when the political conditions in the country are more stable.

If and when, the restoration of the five outports is completed, their capacities will be above pre-war levels, and in addition, it is hoped to install mechanised rice-loading facilities, which will greatly speed up the turn-round of shipping, reduce labour costs and minimise the loss of rice.

The rehabilitation project is divided into several stages. The first will consist of the installation of mooring and channel buoys at Akyab and Maulmain, and the construction of a large pontoon jetty at Mergui. In the second stage, dredging equipment for use at Akyab, Maulmain and Tavoy will be acquired, while the third stage will include the construction of a large pontoon jetty at Maulmain, and pilot's quarters will be rebuilt at the port of Bassein.

Shipping at the new Wharf with completed transit shed.

The Port of Monrovia

A Newly Constructed West African Harbour

SPECIALLY CONTRIBUTED.

INTRODUCTORY

In July, 1948, the Republic of Liberia opened to commercial vessels the port of Monrovia, which is one of the finest on the west coast of Africa, and was financed by the United States Government with lend-lease funds. It was jointly designed by the U.S. Navy's Bureau of Yards and Docks, and by the contractors, Raymond Concrete Pile Company of New York.

Before the United States Government undertook this project, the idea of building a port to accommodate ocean-going vessels had been considered by a number of different interests. For example, about 1926 the Firestone Tyre and Rubber Company entered into an agreement with the Republic of Liberia for the construction of a port at Monrovia. The idea was abandoned, however, because at the site chosen shifting sands made the project impractical, except at prohibitive expense.

Eleven years later, in 1937, the Liberian Government signed a contract with a Dutch mining company, to develop the iron deposits at Bomi Hill and to build a port at Monrovia. This proposed project also was not proceeded with, because it was discovered that this Dutch mining company was backed with Axis capital.

AGREEMENTS WITH LIBERIA

On March 31st, 1942, after war begun, the United States Government signed a defence agreement with the Republic of Liberia. The first article gave to the U.S. the right to build an army air force base in Liberia and other projects necessary to insure the efficient operation of such defence facilities as might be established.

That was one of the first steps which led to the construction of the port, for on December 31st, 1943, another agreement was signed by the governments of Liberia and the U.S. Article one of this agreement provided, for making U.S. funds available as credits for "surveying the estuary of the St. Paul River and such other sites in the vicinity of Monrovia and Marshall as may be necessary for the satisfactory location of the port, and for the construction of a port and port works and access roads at the estuary of the St. Paul River or such other site in the vicinity of Monrovia or Marshall as may be mutually preferred by the Government of the United States of America and the Government of Liberia."

Article 5 of this same agreement provided, in part that, "a contract shall be entered into between the Government of the Republic of Liberia and an American company, duly incorporated in the United States of America or in the Republic of Liberia and approved by the Government of the United States of America, for the operation of the port during the full period of amortization as shall be hereinafter provided, commencing from the date of completion of the port and port works and access roads or from such earlier date as the port is able to begin receiving ships and cargo."

Articles one, two and four of this agreement culminated in a construction contract signed early in 1944 by the Republic of Liberia, by the Navy's Bureau of Yards and Docks, and by the Raymond Concrete Pile Company of New York.

SITE OF THE HARBOUR

When the engineers arrived in Liberia, their first task was to select a port site. Five possible locations were studied, and after weighing the favourable and unfavourable features, the Bushrod Island site was selected.

Monrovia is therefore located on Mamba Point, a high rocky promontory which juts out into the Atlantic Ocean. The north boundary of the city is the Mesurado River, which empties into the ocean just north of Mamba Point. Directly across the Mesurado from the city lies Bushrod Island, a low sandy piece of land approximately five miles in length and one mile in width. The island is formed by the Mesurado to the south, the larger St. Paul River to the north, and a body of tidal water known as Stockton Creek, which connects the two rivers.

The port site on this island has many advantages: (1) freedom from complicated estuary flow; (2) provides a channel entrance in deep water and escapes the possible formation of a sand bar from littoral drift; (3) has a large undeveloped land area for extensive future port expansion; (4) the main breakwater did not require excessively heavy construction, because it is protected from the maximum 8-foot wave and swell action by the rocky promotory of Mamba Point which juts out into the Atlantic Ocean; (5) the ocean floor and beach at this site is more stable than at any other point on Monrovia Bay; (6) it enabled dredging operations to begin after the first 1,000 feet of the south breakwater was built; (7) such dredging was comparatively easy. The material was disposed of back of the quay wall bulkhead; (8) the spring tide is 3.25 feet, and the neap tide is only 2 feet; (9) the shortest distance between the sea and the iron deposits at Bomi Hill.

PORT SURVEYS

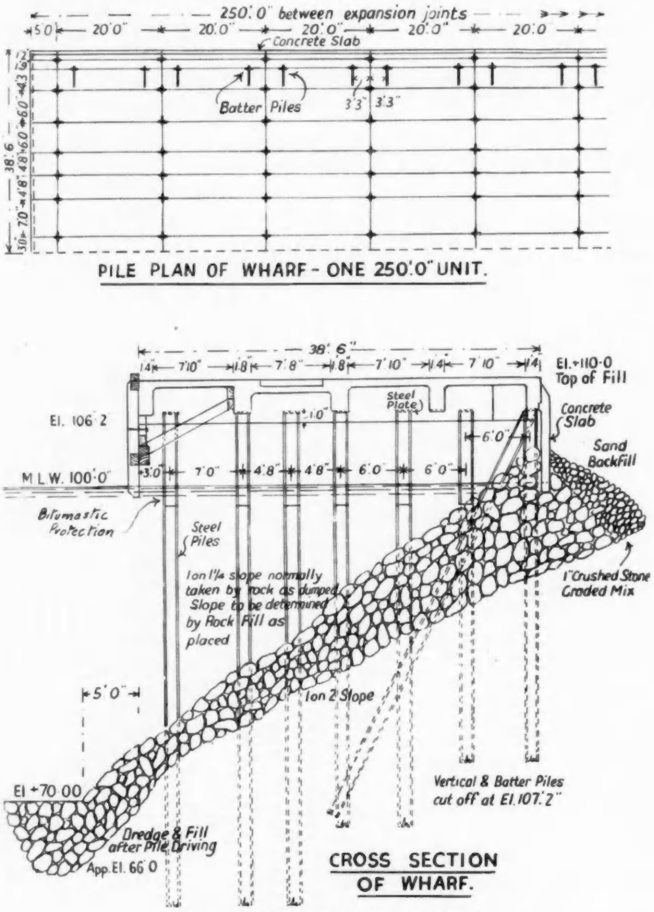
The aerial photographs made by Abram's Aerial Survey in 1936, and those made by the Royal Air Force in 1944, were used to make

The Port of Monrovia—continued

a preliminary key map, and as a basis for surveys. All horizontal survey controls were made from a triangulation point located near the Mamba Point lighthouse. (See map.) Next, permanent concrete monoliths were placed at 800-foot intervals along the shore line of Monrovia Bay from Mamba Point to St. Paul River.

Since there was no available sea level datum, this information had to be compiled by the engineers. The offshore soundings were made with a recording fathometer. Range lines were established on shore at 300 foot intervals. Whenever possible, the inshore soundings were also made with a recording fathometer. But when this was not possible, a hand sounding line was used.

As there was no weather station at Monrovia, preliminary observations were made at a temporary station established at the lighthouse. This station was later replaced by one set up at Camp Johnson, and was equipped with instruments supplied by the U.S. Coast and Geodetic Survey.



Cross Section and Plan of Wharf.

Monrovia is not affected by gales and hurricanes because it is located in the doldrum area. Throughout the year the prevailing winds are from the south-west, but during the dry season they are now and then from the north-east. Their force is never above 5 on the Beaufort scale. During the dry season, November to April, the temperature ranges from 80 to 95 degrees Fahr., with an average humidity of 75 per cent. In the rainy season the temperature ranges from 72 to 85 degrees Fahr., with the humidity above 80 per cent. The rainfall during this season is 160—180-in.

All boring operations were in charge of foremen who had been employed in this kind of work for the Raymond Concrete Pile Company from 10 to 15 years. The offshore and shore borings revealed the soil to be (a) fine sand, (b) medium grey sand, and (c) sand and clay.

THE PORT FACILITIES IN BRIEF

The port consists of an artificial harbour formed by two rock breakwaters approximately 1½ miles out into the open sea, which encompass some 750 acres of protected water. Approximately 150 acres of the harbour area is dredged to accommodate ocean-going steamers, and a marginal wharf 2,000 feet long is capable of berthing four ships. The port is connected with Monrovia by an access road approximately two miles long, and the steel bridge approximately 750 feet in length over the Mesurado River, used as a railroad bridge during constructional work, is now concrete decked for pedestrian and vehicular traffic.

The wharf is approximately 17 feet above mean sea level and the outboard ends are marked by powerful navigation lights.

Covered storage is provided by an 830-ft. long by 81-ft. wide transit shed of structural steel construction. Office space has been provided for administrative and custom activities. Approximately 1,500,000 square feet of fenced open storage is also provided.

BREAKWATERS

About 2,000,000 tons of rock was hauled from the quarry to the two rubble-mound breakwaters, and half of the rocks used were larger than 10 tons each. The south breakwater was completed in June, and the north breakwater in August, 1947.

The south breakwater, 7,702 feet long, begins about one mile north of the Mesurado River. Its outer end is curved northward to protect the harbour entrance from the swells from the south-west and west. Its entire length has a 1 : 1½ slope, and its top width is 20 feet. The average base width decreases from 161 feet at the sea-end to 84.5 feet at the shore-end.

The sea wall, covered with 5 to 8 ton rocks, extends from the south breakwater to the marginal wharf. Its base width averages 58 feet, 20 feet top width, 1 : 1½ slope.

The north breakwater, 7,250 feet long, begins about one mile south of the St. Paul River, it, too, has a 20 feet top width and 1 : 1½ slope, and its base width decreases from 155 feet at the sea-end to 135 feet at the shore-end. Both breakwaters are 17 feet above mean low water level.

The rocks for the breakwaters and sea wall were brought from the quarry in 20-cubic yard steel skips mounted on railway flat cars. At the points of unloading, the skips were lifted from the flat cars by one of the two 50-ton steam whirler cranes with 75 foot booms equipped with special harnesses fastened to their hooks.

After unloading a skip, the crane would return it to the railway flat car. Then the car was switched to the return track by using a portable California cross-over.

The lowest breakwater rock placement was 1,230 cubic yards in one day; and the highest was 4,400 cubic yards.

CHANNEL DREDGING

The distance between the breakwater sea-end centres is 1,022 feet. The channel is 600 feet wide from the entrance to a point 3,910 feet inside the harbour. From this point to the wharf, to provide the harbour with a turning basin, the channel begins to widen out until it reaches a maximum width of 2,250 feet alongside the quay wall.

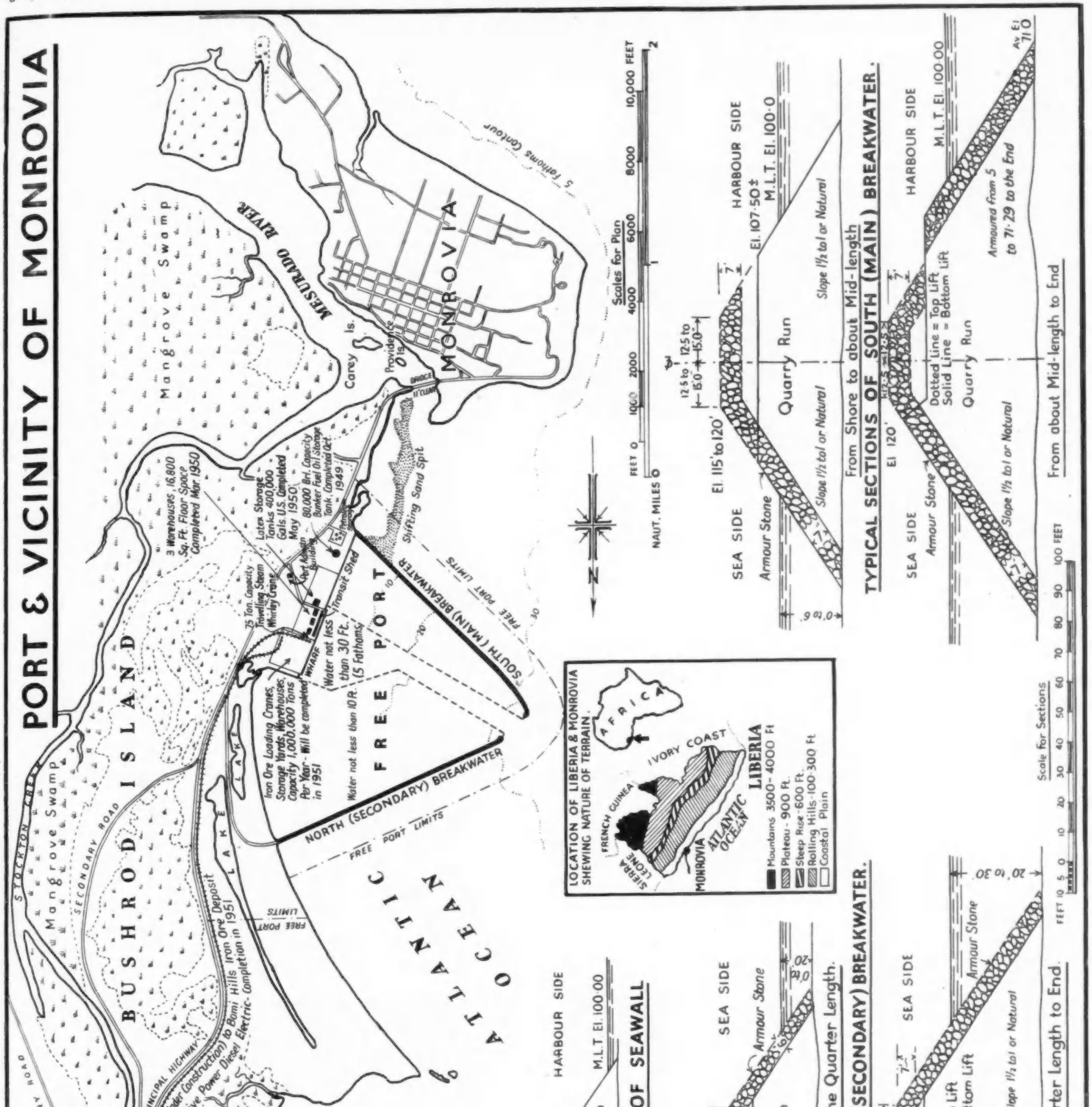
The dredging, covering an area of about 150 acres, to provide a depth of 30 feet of water, required the removal of 3,500,000 cubic yards of sandy clay. This was used as fill, to provide a uniform grade at the back of the marginal wharf retaining wall.

Only one 20-inch hydraulic Diesel electric suction dredge, the "Manatee," was used to perform this task. This dredge, which was brought from New Orleans to Liberia in a Navy LSD, completed the task on June 8th, 1948, after being in continuous operation for 90.5 weeks. The average dredging therefore exceeded 38,000 cubic yards per week. The peak was 70,000 cubic yards in one week.

At the sea-end of each breakwater there is a 33-inch light. One is visible 4 miles; the other, 7 miles. The channel is marked by six red nuns and by six black cans. The two shore range lights are visible a distance of 11 miles. Two lights mark the limit of the marginal wharf.

WHARF

The marginal wharf, 2,000 feet long, 38-ft. 6-in. wide, accommodates at one time four vessels the size of the Liberty ship. The



PORT & VICINITY OF MONROVIA
BUSHROD ISLAND
MONROVIA
FREE PORT
ATLANTIC OCEAN
MESURADO RIVER
ST PAUL RIVER
Mangrove Swamp
Carey Is.
Providence Is.
Shifting Sand Spit
SOUTH (MAIN) BREAKWATER
NORTH (SECONDARY) BREAKWATER
FREE PORT LIMITS
5 fathoms Contour
Water not less than 30 Ft. (5 Fathoms)
Water not less than 10 Ft.
Iron Ore Loading Cranes, Storage Yards, Warehouses; Capacity 1,000,000 Tons Per Year - Will be completed in 1951
3 Warehouses, 16,800 Sq. Ft. Floor Space Completed Mar 1950
Transit Shed
WHARF
Metre Gauge Railway (Under Construction) to Bomi Hills Iron Ore Deposit Motive Power Diesel Electric - completion in 1951
PRINCIPAL HIGHWAY
SECONDARY ROAD
STOCKTON CREEK
NEW GEORGIA
DENNIS LANDING
HAMMY TOWN
VIRGINIA
LAKE
BRIDGE
Scales for Plan
FEET 0 1000 2000 4000 6000 8000 10,000 FEET
NAUT. MILES 0 1 2
LOCATION OF LIBERIA & MONROVIA SHEWING NATURE OF TERRAIN
AFRICA
FRENCH GUINEA
SIERRA LEONE
IVORY COAST
LIBERIA
MONROVIA
ATLANTIC OCEAN
Mountains 3500-4000 Ft.
Plateau - 900 Ft.
Steep Rise - 600 Ft.
Rolling Hills - 100-300 Ft.
Coastal Plain
TYPICAL SECTION OF SEAWALL
LAND SIDE
HARBOUR SIDE
El. 110.00
Dredge Fill
Slope 1½ to 1 or Natural
Quarry Run
M.L.T. El. 100.00
TYPICAL SECTIONS OF NORTH (SECONDARY) BREAKWATER.
HARBOUR SIDE
SEA SIDE
El. 110' to 118'
M.L.T. 100.00
Armour Stone
Quarry Run
From Shore to about One Quarter Length.
El. 118.00
Dotted Line = Top Lift
Solid Line = Bottom Lift
Harbour Side Armoured from Mid-length to Outer End
From about One Quarter Length to End.
TYPICAL SECTIONS OF SOUTH (MAIN) BREAKWATER.
SEA SIDE
HARBOUR SIDE
El. 115' to 120'
El. 107.50±
M.L.T. El. 100.0
Armour Stone
Quarry Run
From Shore to about Mid-length
El. 120'
M.L.T. El. 100.00
Armoured from 5 to 71.29 to the End
From about Mid-length to End
Scale for Sections
FEET 10 5 0 10 20 30 40 50 60 70 80 90 100 FEET

The Port of Monrovia—continued

The Old and the New—Construction Equipment arriving at Monrovia.

deck is supported on bituminous coated 14-inch steel " H " piles at the rate of 115 piles per 250-foot section, with the exception of the crane-way area, which has 182 piles per 250 feet.

The retaining wall consists of precast concrete slabs on the in-shore side of the wharf, which extend to a depth of 8 feet below the mean low water level. In addition, there is rock fill placed at a 1 : 1½ slope. This construction was used because the tidal range is not over two feet.

Wooden fenders are used to protect the wharf from vessel damage; they are suspended from the deck and extend only a few feet below the mean low water level. Each 250-foot section of the deck is equipped with four cleats and 2 bollards.

Under the concrete deck of the wharf (which has a live-load capacity of 500 psi.), there is hung an 8-inch water pipe line supplied from a 15,000-gallon water tower, a 6-inch bunker fuel pipe line fed from 10,000-barrel tanks, and a 6-inch Diesel oil pipe line supplied from 5,000-barrel tanks. Each of these pipe lines has a number of outlets along the edge of the wharf. In the construction of which, provision was also made for the laying of railroad tracks when desired.

TRANSIT SHED

The transit shed on the wharf is an 830 by 80 foot structure with a 20 foot clearance from the floor. It has a steel frame and asbestos cement roof and sides. The base of the sides, however, is made of concrete blocks 5 feet high. Two skylights run the full length of the building. Ventilators of 36-in. size are mounted on the roof.

This shed provides about 65,000 square feet for the storage of cargo, in addition to the space allotted for passenger, administrative, and customs facilities.

OTHER FACILITIES

Adjacent to the transit shed there is about 1,500,000 square feet of fenced-in open storage space. The present petroleum products storage tanks have a combined capacity of 1,500,000 gallons. Separate areas have been allocated for the installation of cold storage facilities; latex storage tanks; and ore storage and loading facilities. On the marginal wharf there is a 50-ton American Hoist & Derrick steam whirler crane with a 75-foot boom. This crane will be used to load and discharge heavy cargo.

The port facilities include adequate sanitary facilities. There is an 82-ft. × 30-ft. concrete power house, with a corrugated asbestos roof and wooden louvers, equipped with three 75 K.W. Caterpillar Diesel-General Electric generator units, and a small machine shop. There are two 28-ft. × 16-ft. one-storey concrete block pump houses with corrugated asbestos roofs. These pump houses are located over shallow wells near a small fresh water lake. The water is sand filtered and treated with chlorine. Each pump house is equipped with a 500-gallon per minute capacity Chrysler pump.

All cargo will be discharged by ships' tackle, except for heavy lifts, for which the 75-ton steam crane is available, situated on tracks across the quay at the northern end of the transit shed. Both the quay and the shed are adequately provided with lights for night work.

With regard to tugs, this service will be provided by three converted tank landing craft. Pilotage is compulsory.

A first-class road has been constructed from the harbour to Monrovia, for the removal of cargo from the warehouses now in course of construction.

From recent observations during heavy weather, there is little or no swell inside the harbour, but during winds a slight amount of surging is experienced.

CONSTRUCTIONAL WORK

Because the construction schedule was upset by the great distance from the New York base (3,965 nautical miles), by the rainy season, and by the priority of materials for the armed forces during the war, the job extended from May, 1944, when the engineers arrived in Liberia, to June, 1948, when the port was completed for commercial vessels usage.

About 50,000 tons of materials and equipment used in this project were unloaded ½ to ¾ miles off shore in the open sea from freighters into lighters. First, 10-oared native surf boats were used to bring the cargo ashore. Later, Navy landing craft were used for this service. But, in spite of this difficult method of handling cargo, very little was actually lost. And what is more, the contractor soon became so efficient in operating the Navy landing craft that he could take on cargo in 15-foot waves as the freighters dragged at their anchors.

As about 1,800 natives were employed on this project, the contractor had to be a teacher as well as a builder, because most of the natives had never before seen steam locomotives, power shovels, and other construction equipment.

With the co-operation of the Liberian Government, an apprenticeship school was established. The natives were both friendly and willing to learn, and as a result, some of them attained considerable technical proficiency.

The difficulty in getting sufficient construction equipment, because of the war, was partly overcome by borrowing compressors, air drills, bits, tank lighters, a dory, a crawler crane, a tug and other equipment from the U.S. Army. Even the lifeboat from a shipwreck was salvaged from the beach and converted into a launch. The Firestone Plantations Company, a subsidiary of the Firestone Tyre and Rubber Company, helped by supplying some tools and other equipment.

Sometimes, during the war, there was only six weeks' supply of equipment and supplies ahead of the construction schedule because of the difficulty in obtaining such things.

The South Breakwater nearing completion.

The Port of Monrovia—continued

QUARRY OPERATIONS

The 4,000,000 tons of rock needed for railroad ballast, for access roads, for concrete aggregate, and for the two breakwaters, was taken from a quarry located on the south side of Mamba Point.

The stone in this quarry is an abrasive diabase or basalt rock with a specific gravity of 3.02, or 190 lb. per cu. ft. Its average hardness is B-17 on the Rockwell scale; and it is between 6 and 7 on the Moh scale.

Because of the unusual hardness of the rock, two difficulties were encountered. At first the blasts did not always break the rock into small chunks, with the result that secondary drilling was required before it could be fed into the stone crushers. Second, the best production in this hard rock, with its many crevices and seams, was about 6 feet of hole per churn drill per shift. After each 1½ to 2½ feet of drilling, the bits had to be resharpened on one of the two No. 12 Bucyrus-Erie bit sharpeners. For example, for one 42-day period a total of 1,092 churn drills were needed to drill 2,425 feet of 8-inch diameter holes an average depth of 85 feet.

Bentonite, a colloidal clay, was used to hold cuttings in suspension and free them from the cutting edges of the bits. In fact, it acted as a lubricant and reduced the rate of gauge loss.

A total of 18 Bucyrus-Erie 29T churn drills, each with a 2,400-pound string of tools and 8-inch paddle type carbon steel bits, were used in the quarry to drill holes spaced 20 feet from centre to centre.

The holes were filled with sticks of dynamite 2 feet long and 7 inches in diameter. One serious accident occurred in this phase of the project's operations. Due to a premature explosion, one foreman and three natives were killed loading a churn drill hole.

The greatest blasting operation took place on May 4th, 1946. On that day, 150,000 cubic yards of rock was unloosened when 104 holes with 52 tons of powder were exploded.

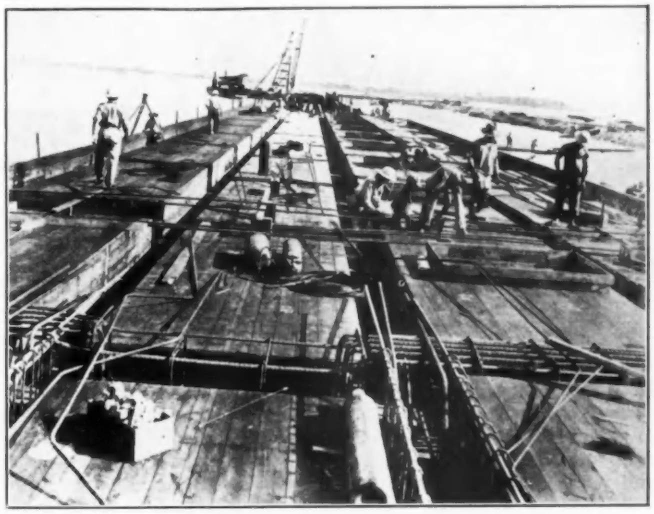
After each blast the rocks were loaded into dump trucks, and into skips on flat cars with three 5 cubic yard Bucyrus-Erie electric shovels equipped with drag lines. Frequently they handled rocks twice the size of their shovels.

The rock used for roads, concrete aggregate, and railroad ballast was transported to two Smith Engineering Works rock crushing units with a capacity of 50 tons per hour each.

RAILWAY AND BRIDGES

To haul rock from the quarry to the crushers and to the breakwaters, to convey supplies and equipment to and from workshops and storage areas, and to transport personnel between Camp Johnson and construction operational points, it was necessary to build a standard gauge railroad, access roads, and a bridge across the Mesurado River.

The Wm. V. S. Tubman Bridge over St. Paul River.



Wharf under construction.

This 790-foot long trestle bridge, with two 3-ft. 3-in. pedestrian walks, and a 20-ft. 8-in. vehicle way, has an overall width of 30 feet. Its 27 spans are supported by bituminous coated steel " H " piles. When used by the construction forces and the railroad, it had a timber deck, but now has a 12-inch thick concrete deck.

A reinforced concrete and steel bridge has also been built across the St. Paul River, carrying the railway, now under construction, from Monrovia to Bonri.

To connect the various mainland construction activities with Bushrod Island and with the sea-ends of the breakwaters, a standard gauge railroad about 8 miles long also had to be built. The rail haulage from the quarry to the shore-end of the south breakwater was 3 miles; and the distance to the north breakwater shore-end was 4½ miles.

The rolling stock of this construction railroad consisted of nine 50-ton Porter steam locomotives, four 50-ton hopper cars, four 50-ton side dump cars, and 95 flat cars used in conjunction with 83 20-yard capacity skips.

CONSTRUCTION PLANT AND EQUIPMENT

In the construction area there were facilities for making any type of repair on construction equipment. The carpenter shop was provided with power saws and other devices. The machine shop was complete with lathes, drills, and other tools. The blacksmith shop was equipped with the latest type of electric salt bath furnaces and automatic bit dressing machines. In the power house there was installed three Superior Diesel generator units of 450 K.W. each, which supplied the light for the entire project, the power needed in the shops, and to operate the power shovels and some of the other equipment.

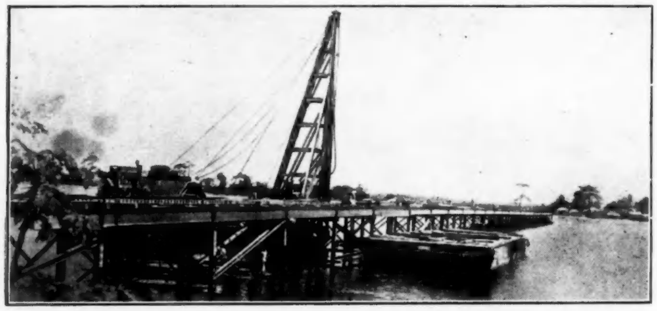
SOME OF THE EQUIPMENT AT MONROVIA

Besides the machinery mentioned above, there were: two wooden barges; one steel oil barge; three LCM's (U.S. Navy); two small tugs; 10 caterpillar tractors with bulldozers; one Adams road grader; four Northwest cranes or shovels; one truck-mounted crane; one ambulance; 19 dump trucks; two oil tank trucks; eight Euclid rock trucks (10-yd.); two Autocar trucks (10-yd.); several buses and jeeps for transporting personnel; one Ingersoll-Rand air compressor (1,075 cfm.); four Gardner-Denver air compressors (500 cfm.); two Le Tourneau scrapers (8-yd.); two Wooldridge scrapers (12-yd.); one Ransome concrete mixer (1-yd.); and two Koehring mixers (½-yd.).

ACCOMMODATION FOR PERSONNEL

Camp Johnson was equipped with facilities to make the 225 American workmen comfortable, safe and contented. For these

The Port of Monrovia—continued



Steel-piled Construction Bridge, later fitted with a reinforced concrete deck, connecting Monrovia with the Port Area.

workmen were built ten 20-men barracks with two men to a room; special quarters for the supervisory staff; a central galley and mess hall, which also served as a motion picture theatre; a recreation hall with a commissary, a radio, and card, ping-pong and pool tables; a laundry; three shower bath houses connected with covered walks to the barracks; and adequate sanitary and water supply systems. The sick and injured were cared for in a competently staffed 10-bed hospital equipped with operating, X-Ray and other essential equipment.

THE PORT'S OBJECTIVES

The port aims to invite domestic coastwise and foreign trade, and trans-shipment taffic, and to aid in developing the resources of Liberia and adjoining countries.

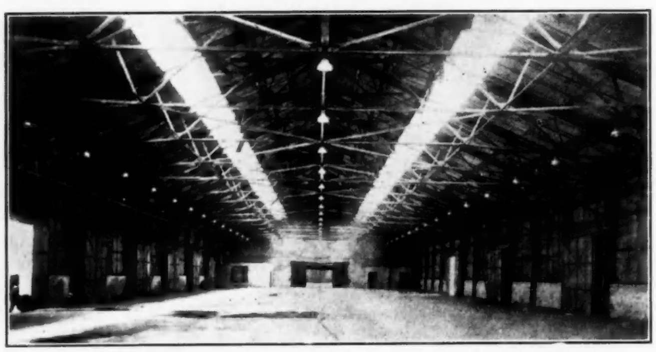
This latter objective, however, depends upon the development of better means of communications, for at present there is no railroad in Liberia. There are only 450 miles of roads, built for light vehicular traffic. Communication with the interior is largely by trailways, and the Liberian waterways, like many other African rivers, are limited because of waterfalls.

The port of Monrovia, built on the open sea and undeveloped land, should materially aid in the development of Liberia. This country of some 43,000 square miles and 1,500,000 population, extends along the Atlantic for 350 miles from the French colony of Ivory Coast on the east to the British colony of Sierra Leone on the west. The hinterland penetrates from 75 to 150 miles from the coast.

Within this small area the rubber industry predominates. And yet, besides rubber trees, Liberia has great forests of hardwoods, ore deposits with a 70 per cent. iron content, gold, and a variety of tropical vegetable products.

All the cargo that has formerly been discharged and loaded at Marshall, Cape Palmas and other Liberian coast ports, will be landed at Monrovia and forwarded to the final destination by the Farrell Line. This is a "feeder service," which operates the m.v. "African Guide" of about 500 tons d.w., taking 12 saloon passengers and a large number of deck passengers.

When President William V. S. Tubman of Liberia formally opened the port of Monrovia on July 26th, 1948, the 101st anniversary of the Republic, he dedicated the north breakwater to the late U.S. President Roosevelt.



Interior of Transit Shed, shewing ample glazing and lighting.

In keeping with article five of the agreement signed on December 31st, 1943, the port is controlled by the Monrovia Port Management Company, Ltd., comprising seven American business organisations operating in Liberia. The Port Operating Committee consists of representatives of these companies and the Liberian Government.

It is interesting to note that although the port has been open only since July, 1948, the first year's business far exceeded expectations and a substantial sum was cleared over operating costs. This most certainly indicates a worth-while undertaking.

Lighthouse Equipment for Monrovia

Arrangements have been made for the two principal lighthouses in Liberia to be equipped with the most modern type of marine lighting apparatus. The first of these installations, at Monrovia, is made necessary because the importance of the new port is likely to increase fairly rapidly, and it is therefore necessary that an adequate and reliable lighthouse be installed.

A light, operated on the petroleum vapour system, has been in existence for many years on a headland at the approach to Monrovia. This light will be electrified in accordance with the latest practice; its power will normally be provided by the town's electricity supply, but should this fail, or fluctuate, a diesel engine driven generating set will start up automatically to keep the light operating. Upon the restoration of the mains supply, the generating plant will shut down automatically. Should the lamp inside the optical apparatus burn out during the night, the keeper will be warned by an alarm bell.

The second lighthouse, at Cape Palmas, is probably the most important along the West African coast from Sierra Leone to Fernando Po, as in the past there have been wrecks at this point. It is therefore essential that a powerful and up-to-date light be installed. In this instance, the revolving optical apparatus, with its cage of glass prisms, is illuminated by an electric filament lamp and rotated by an electric motor. Should either fail, a stand-by apparatus is brought into service automatically. Power for the lighthouse is generated on the site by one of the three diesel engine generating sets, started and stopped by push buttons. Should the set fail, the keeper is warned by a bell to start up a reserve set. A small indicator shows where the fault lies for the guidance of the visiting service mechanic. The three sets are provided so that, even during the period when one set is being overhauled, an operating and reserve set are available. A photo-electric switch notifies the keeper when to start the generating plants by means of a bell when daylight fades. If the keeper should attempt to switch off before daybreak, the bell will ring continuously until he restarts the engine. After the failure of the lamp inside the optical apparatus, the warning light is illuminated on the control panel which the keeper cannot extinguish until he has replaced the lamp inside the lantern.

The light at Monrovia will be arranged to give a single white flash, of approximately 180.000 candle power, every 12 seconds. The new light at Cape Palmas, will give a double flashing character, flashing twice every 20 seconds with a candle power of over 450.000 candles. Both these lights will be seen in clear weather well beyond the horizon, where the light will be reflected in the sky.

The entire equipments, including generating plants for both lighthouses is being manufactured by Chance Bros., Ltd., of England.

New Moroccan Fishing Port.

A new fishing port is being built at Soueira-Keldima, which is situated in a small natural bay between Safi and Mogador on the Southern Moroccan coast. The construction works are being financed by a private corporation who have already built a well-equipped fish canning factory. When completed, modern trawlers will operate from the new port.

Locomotives for Heavy Dock Shunting

Comparative Running Costs of Steam and Diesel Engines

By A. O. HELPS, A.M.I.Mech.E., M.I.Struct.E.
Chief Assistant Engineer (Mechanical) Port of Bristol Authority.

(continued from page 44)

The employment of straight diesel shunting locomotives in docks, steel works and industrial yards is increasing rapidly and will no doubt continue to do so. In the first part of this article, the comparative running costs of steam and diesel shunting engines were dealt with, and it is thought that the present instalment, giving comparable tabulated main details, together with adhesion factors and weight required by both steam and diesel industrial shunting locomotives, will be of interest to those contemplating replacement of existing steam engines by diesel or ordering new ones.

Efficient and satisfactory performance of industrial shunting operations depends upon the correct relationship between the maximum tractive effort the locomotive can exert and the total service weight carried by its driving or coupled wheels. Thus, if the weight be too small, the locomotive is overpowered and the wheels will slip too easily, with consequent rapid tyre wear and other ill effects on the locomotive. If the weight be too great the locomotive is underpowered, which means so much dead weight to be moved about without any advantage to the locomotive.

In adjusting the best proportion of maximum rated tractive effort and weight, due regard has to be paid to the character of work the locomotive will have to perform.

Steam locomotives for **general industrial shunting purposes** require a driving weight of at least five times the maximum tractive effort obtainable by cylinder power. Straight diesel shunting locomotives require a driving weight of at least four times their maximum rated tractive effort. With diesel electric shunting locomotives, the driving weight must be at least three and a half times the maximum starting tractive effort. The reduced weight required by this type of locomotive is due to the fact that the torque at its driving wheels is more uniform than that of a reciprocating engine with final drive through connecting rods.

In order to ascertain if a locomotive is well balanced in regard to rated maximum tractive effort and adhesion, certain very elementary calculations are necessary, viz.:—

(a) Calculation of the maximum tractive effort available.

(b) Calculation of service weight required in the locomotive to give adequate adhesion.

(1) For industrial steam locomotives having two cylinders:—

let TE = maximum tractive effort available in pounds,
d = diameter of cylinder in inches,
l = stroke of piston in inches,
.8 = constant usually taken as .8 representing 80% of boiler pressure effective in cylinders,
P = working pressure of locomotive boiler in lbs. per sq. inch,
DW = diameter of driving wheels in inches,

then Maximum Tractive Effort, TE, in lbs. $= \dfrac{d^2 \times 1 \times P \times .8}{DW}$

(2) For straight diesel locomotives:—

where TE = maximum rated tractive effort in pounds,
BHP = brake horsepower of prime mover,
.8 = 80% overall mechanical efficiency of locomotive,
S = speed in miles per hour,

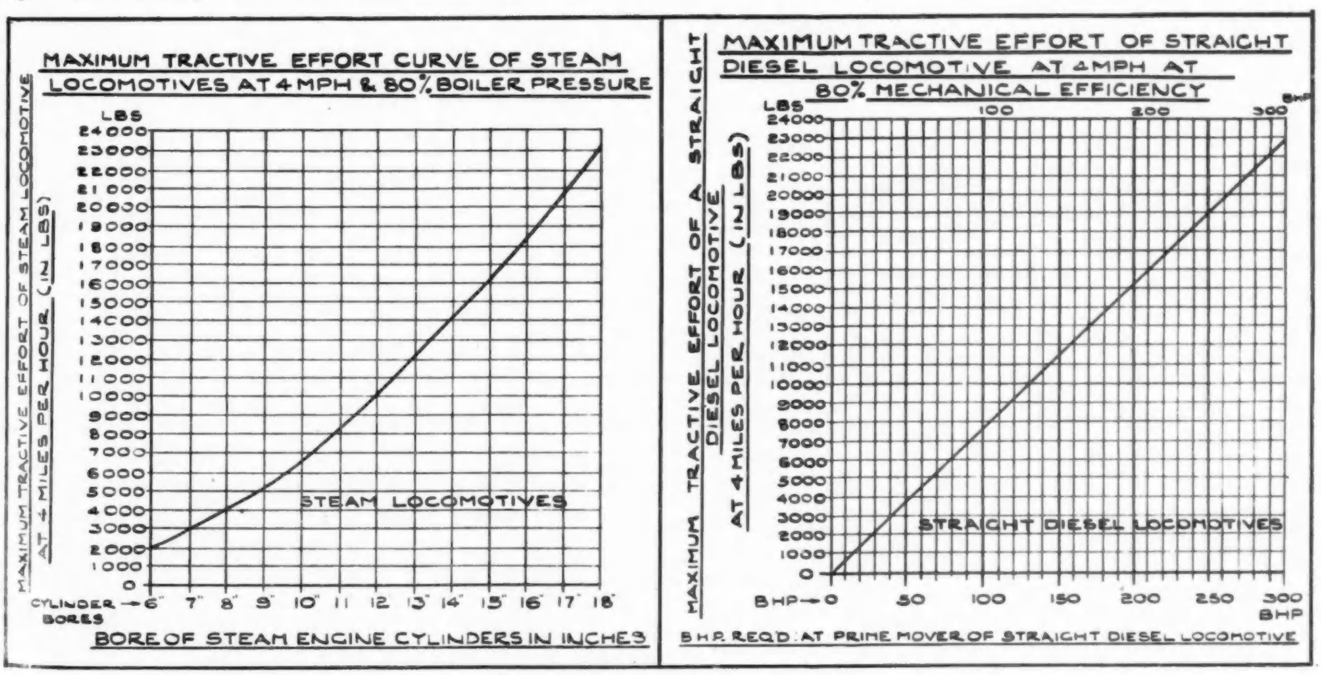


Fig. 1. Comparative Steam and Straight Diesel industrial shunting locomotives.

Locomotives for Heavy Dock Shunting—continued

INDUSTRIAL STEAM SHUNTING LOCOMOTIVES MAXIMUM TRACTIVE EFFORT AT SAY 4 MILES PER HOUR BASED ON 80% BOILER PRESSURE EXAMPLES OF LOCOMOTIVES ACTUALLY MANUFACTURED				INDUSTRIAL STRAIGHT DIESEL SHUNTING LOCOMOTIVES MAXIMUM TRACTIVE EFFORTS AT SPEEDS STATED AND BASED ON 80% MECHANICAL EFFICIENCY.			
PARTICULARS OF STEAM LOCOMOTIVE & WEIGHT IN WORKING ORDER	MAXIMUM TRACTIVE EFFORT AT 4 MPH	ADHESION FACTOR IN WORKING ORDER	NETT HAULAGE CAPACITY AT 24 lbs PER TON RESISTANCE	PARTICULARS OF STRAIGHT DIESEL LOCOMOTIVE & WEIGHT IN W.O. & RATING OF PRIME MOVER	MAXIMUM TRACTIVE EFFORT IN lbs AT 80% EFF	ADHESION FACTOR IN WORKING ORDER	NETT HAULAGE CAPACITY IN TONS AT 24 lbs PER TON RESISTANCE
14" × 22" × 180 lbs □" DRIVING WHEELS 43" DIA W'T IN WORKING ORDER 35 TONS	14,400 lbs	5·43 γ = ·184	565 TONS = 16 TIMES W'T OF LOCO' IN WORKING ORDER	170/187 BHP LOCOMOTIVE 187 BHP 1 HOUR TRACTION RATING WEIGHT SAY 26 TONS	14,000 lbs AT 4 MPH	4·17 γ = ·24	558 TONS = 21·4 TIMES WEIGHT OF LOCO' IN WORKING ORDER
15" × 21" × 180 lbs □" BP DRIVING WHEELS 43" DIA WEIGHT 40 TONS	15,800 lbs	5·67 γ = ·176	620 TONS = 15·5 TIMES W'T OF LOCO' IN WORKING ORDER	186/204 BHP LOCOMOTIVE RATING 10% OVERLOAD OR 1 HOUR TRACTION RATING W'T IN W.O. = 30 TONS	15,280 lbs AT 4 MPH	4·4 γ = ·227	606 TONS = 20 TIMES WEIGHT OF LOCO IN WORKING ORDER
16" × 24" × 170 lbs □" DRIVING WHEELS 46" DIA W'T IN WORKING ORDER 42 TONS	18,000 lbs	5·25 γ = ·191	708 TONS = 16·8 TIMES W'T OF LOCO' IN WORKING ORDER	225/250 BHP LOCOMOTIVE 250 BHP = 1 HOUR TRACTION RATING W'T IN WO SAY 36 TONS	18,700 lbs AT 4 MPH	4·3 γ = ·232	745 TONS = 20·6 TIMES WEIGHT OF LOCO' IN WORKING ORDER
17" × 24" × 180 lbs □" 75% BP DRIVING WHEELS 45" DIA WEIGHT 44½ TONS	20,800 lbs	4·8 γ = ·208	822 TONS = 18·5 TIMES LOCO' W'T	250/275 BHP LOCOMOTIVE 275 BHP = 1 HOUR TRACTION RATING WEIGHT OF LOCO' 40 TONS	20,700 lbs AT 4 MPH	4·35 γ = ·23	823 TONS 20·6 TIMES LOCO W'T
16" × 26" × 180 lbs □" DRIVING WHEELS 54" DIA WEIGHT 47 7 TONS	22,400 lbs	4·75 γ = ·21	887 TONS = 18·5 TIMES LOCO' W'T	300 BHP LOCOMOTIVE 300 BHP 12 HOUR RATING WAS SPECIFIED IN THIS CASE W'T IN W.O. 45 TONS	23,500 lbs AT 3·8 MPH	4·28 γ = ·234	937 TONS = 20·8 TIMES W'T OF LOCOMOTIVE IN WO

Fig. 2. Table showing comparative data of modern industrial Steam and Straight Diesel shunting locomotives.

then Maximum Tractive Effort, TE, in lbs. $= \dfrac{\text{BHP} \times 375 \times .8}{S}$

Let γ = Coefficient of adhesion (wheels to rails),

W = Weight of locomotive on driving wheels,

Then $W\gamma$ = the maximum possible tractive effort which can be developed at given weight.

The generally accepted values of the adhesion coefficient γ are given in the following table, together with the equivalent adhesions in pounds per ton of locomotive weight.

Table of Adhesion Coefficients.

Condition at Rail	Value of adhesion Coefficient γ	Equivalent adhesion in pounds per ton of locomotive weight
General ordinary English weather	γ = .2	450 lbs. per ton
Rails very dry	γ = .268	600 lbs. per ton
Rails very wet	γ = .245	550 lbs. per ton
Rails greasy	γ = .13	290 lbs. per ton
Frost or snow	γ = .09	200 lbs. per ton

It is obvious that the general design weight would be excessive and uneconomical if the weight of the locomotive was designed to give the maximum rated tractive effort at the extreme case of snow or frost on rails, and from analysis of many examples of each type of locomotive for shunting duties, viz., steam, straight diesel and diesel electric, the following adhesion particulars have been obtained:—

Type of Industrial Locomotive	Usual allowance for γ value	Equivalent adhesion lbs. per ton of locomotive weight	Adhesion factor of Locomotive
Steam Locomotive	γ = .19	425 lbs. per ton	5.25
Straight Diesel Locomotive	γ = .237	530 lbs. per ton	4.2
Diesel Electric Locomotive	γ = .26	585 lbs. per ton	3.85

The adhesion factor of a locomotive:

$$= \frac{\text{Weight of Locomotive in lbs.}}{\text{Maximum Rated Tractive Effort in lbs.}}$$

Let us now analyse a given case for both a well designed steam and straight diesel shunting locomotive.

CASE I—STEAM LOCOMOTIVE

Cylinder Bore 16-in. = d

Stroke 24-in. = 1

Boiler Pressure 170 lbs. = P

Dia. of Driving Wheels = 46-in. = DW

Weight in working order = 42 tons.

From (1)

$$\text{Maximum Tractive Effort in lbs.} = \frac{d^2 \times 1 \times P \times .8}{DW}$$

$$= \frac{16^2 \times 24 \times 170 \times .8}{46} = 18{,}000 \text{ lbs. tractive effort.}$$

Weight in Working Order = 42 tons.

$$\therefore \text{Adhesion Factor} = \frac{42 \times 2240}{18000} = 5.25$$

$$\text{and } \gamma = \frac{1}{5.25} = \gamma = .191$$

Tractive Effort available from adhesion coefficient of $\gamma = .191$

$$= W\gamma = 42 \times 2240 \times .191 = 18{,}000 \text{ lbs.}$$

The tractive effort available both from cylinder power and from adhesion are balanced, and the adhesion factor of **5.25** is in accordance with industrial steam locomotive design.

CASE II—STRAIGHT DIESEL INDUSTRIAL LOCOMOTIVE

Prime Mover = 300 BHP.

Weight in working order = 45 tons = W

Speed at which maximum tractive effort is to be available = 3.8 mph. = S

Locomotives for Heavy Dock Shunting—continued

Mechanical overall efficiency = 80%.

Then from (2) Maximum Tractive Effort $= \dfrac{\text{BHP} \times 375 \times .8}{\text{S}}$

$$= \frac{300 \times 375 \times .8}{3.8} = 23{,}500 \text{ lbs. Max. Tractive Effort.}$$

$$\text{Adhesion Factor} = \frac{45 \times 2240}{23500} = 4.28$$

$\gamma = .234$

$\therefore$ Tractive Effort from adhesion weight $= W\gamma$

$= 45 \times 2240 \times .234 = 23{,}500$ lbs.

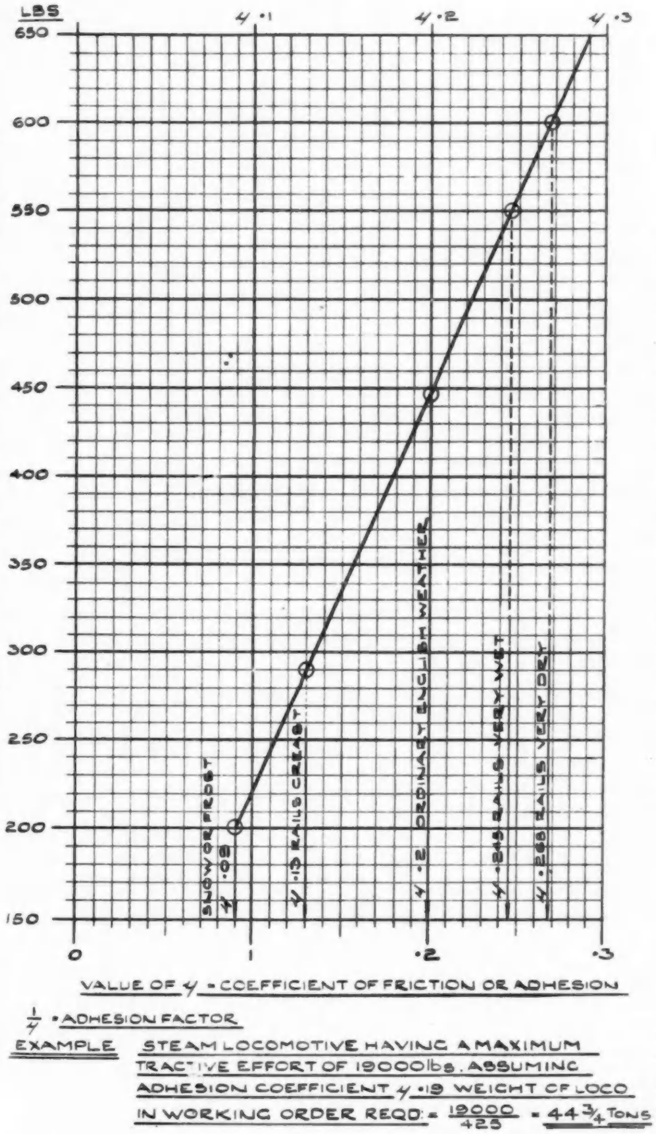


Fig. 3. Curve relating adhesion co-efficient and adhesion per ton of loco weight.

The tractive effort from BHP of prime mover and from adhesion are balanced and the adhesion factor of 4.28 is adequate for this class of locomotive.

The two examples given above represent a sound basis of design for the respective class of locomotive, and it cannot be over emphasised that the power available and the adhesion of a locomotive should be suitably proportioned on the above lines, and the *minimum* adhesion factors permitted should be as follows:

Steam Industrial Shunting Locomotives ...	5 to 1.
Straight Diesel Shunting Locomotives	4 to 1.

Where steep gradients are encountered these adhesion factors need to be increased considerably, but such cases will receive special consideration by the makers.

SELECTING STEAM AND STRAIGHT DIESEL LOCOMOTIVES OF COMPARABLE MAXIMUM TRACTIVE EFFORT

Fig. 1 depicts two graphs from which equivalent steam and straight diesel locomotives may be selected. These are based on similar maximum rated tractive efforts at a speed of 4 miles per hour in each case.

Example.—Assume the maximum tractive effort required at 4 miles per hour to be 18,000 pounds, then from the steam locomotive graph an engine having cylinders of 16-in. bore will be required, and from the diesel graph a straight diesel with a prime mover of 240 BHP will be required; or assuming the tractive effort required to be 16,000 pounds at 4 miles per hour, the steam locomotive would require cylinders of 15-in. bore and the equivalent straight diesel locomotive would require a prime mover developing 212 BHP.

In order to simplify these comparison, a tabulated list of steam and straight diesel shunting locomotives of sizes likely to be required for docks or general industrial shunting duties has been prepared and is given in Fig. 2. The main particulars of both types of locomtives are clearly indicated. The comparative maximum tractive efforts and adhesion factors, etc., together with the required weights of the locomotives are given in each case. The nett haulage capacity of each locomotive is also indicated, and this is based on a total resistance of 24 lbs. per ton to cover starting resistance and acceleration (on industrial track).

As an approximate basis of haulage capacity, it may be assumed that a steam shunting locomotive will satisfactorily haul 16 times its own weight in working order and that a straight diesel locomotive will haul satisfactorily about 20 times its own weight in working order.

The general particulars given in Fig. 2 are of locomotives actually made by well known British makers, and it will be seen that the adhesion factors, etc., resemble closely those recommended in this article.

Fig. 3 indicates a graph relating adhesion coefficients γ, and adhesion per ton of locomotive weight for various conditions existing at rails. From this graph, intermediate values to those given in the two tables may be rapidly ascertained.

Example from Fig. 3.—Assume that it is required to ascertain the necessary service weight of a steam locomotive having a maximum rated tractive effort of 18,000 pounds. Condition: ordinary English weather, γ value say .19 from curve adhesion per ton of service weight = 425 pounds.

$$\therefore \text{Required service weight} = \frac{18000}{425} = 42 \text{ tons.}$$

When replacing industrial steam shunting locomotives by straight diesel locomotives, it should be remembered that the power output of the steam locomotive rises with the rail speed, but that of the diesel locomotive remains more or less constant throughout the speed ranges of the gear box, and on account of this fact it is not advisable to cut the proposed power of the diesel locomotive to a minimum, but rather to ensure that there is a reserve of power to boost up the performance at the higher speed ranges.

For some years the writer has observed that the tendency of some diesel locomotive manufacturers has been to base the performance of their products on the one hour 10% overload rating of the prime mover. This is referred to sometimes as the "Traction rating," but it is considered extremely unwise to adopt this basis, especially in the case of locomotives performing shunting operations in docks, steelworks, etc., where loads are frequently excessive and the permanent way in an indifferent state of repair.

Locomotives for Heavy Dock Shunting—continued

It is felt that for heavy duty shunting as found on docks and steelworks, etc., the prime mover should most certainly be assessed on its continuous or twelve hour rating.

Again, some makers, when calculating the tractive efforts of the locomotive, assume an overall mechanical efficiency for the straight diesel locomotive of 85%; here again, it is considered that an overall mechanical efficiency of 80% represents more truly the efficiency to be expected, and from analysis of some more recently constructed straight diesel locomotives it is found that there is a tendency by some of the best makers to rate this type of locomotive rather more conservatively than in the past, viz.:

(a) To calculate the tractive efforts from the 12 hour or continuous rating of the prime mover.

(b) To assume an overall mechanical efficiency for the straight diesel locomotive of 80%.

The writer feels this policy of more conservatively rating the diesel locomotive has been long delayed, but that ultimately the above allowances will be general, with satisfaction to all concerned, and particularly the staffs responsible for maintenance of these diesel locomotives.

Reconstruction of Barry Commercial Dock

Novel Methods Employed in Conversion of Old Dry Dock

(Specially Contributed)

For the past eight months work has been in progress and is now rapidly approaching completion upon the conversion of the ancient Barry Commercial Dry Dock.

The work in question has been undertaken by Messrs. C. H. Bailey, Ltd., the well-known ship repairing firm operating in the South Wales ports, who recently obtained a long lease of the Dry Dock from the Docks and Inland Waterways Executive.

The old dry Dock was built about 50 years ago at the period when the port of Barry was being developed so as to cope with the great expansion of the coal export business which was then in progress.

The requirements of a dry dock for the type of vessel that was in use in those days were, of course, different from those of to-day, and it became necessary, therefore, to undertake very extensive alterations in order to bring the dry dock into line with modern needs.

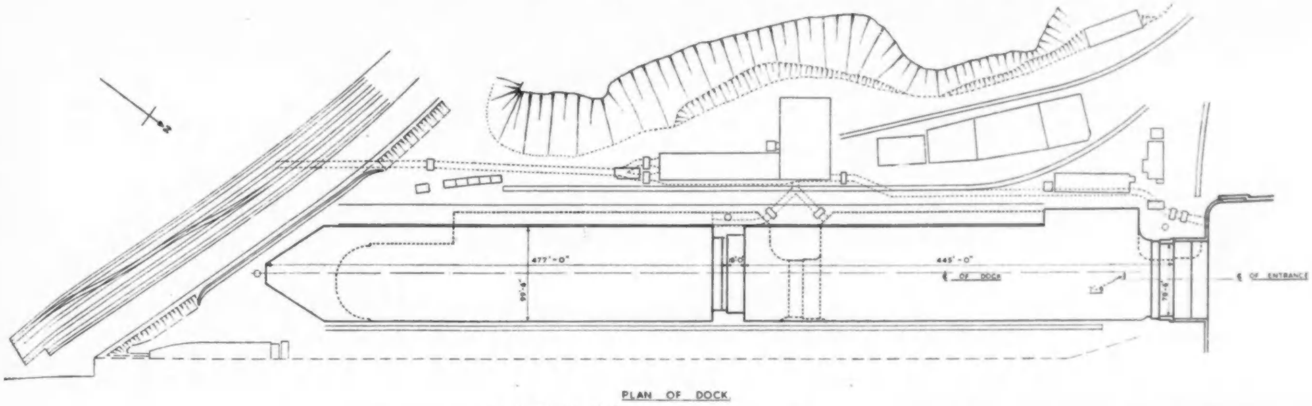
The old dry dock was intended to dock four ships at a time, two ships abreast in the near part and two other ships abreast in the nether part, the two parts being separated by an intermediate entrance closed by a floating steel caisson gate, the gate itself being identical with the caisson gate which separates the dry dock as a whole from the main wet dock or Basin outside.

The peculiar feature of the old arrangement was that the width of the outer and inner entrances closed by the two caisson gates at cope level was only 60-ft., whereas the width of the dry dock itself was 113-ft. 6-in. The overall length of the near portion of the old dock was 384-ft. and of the nether portion was 478-ft.

In the reconstruction the sub-division of the whole dry dock into two portions by means of an inner caisson gate is being retained but the position of the inner gate has been altered and a considerable lengthening of the dock at the nether end has been effected. At the same time, the

Fig. 2. View of Work in Progress.

Reconstruction of Barry Commercial Dock—continued



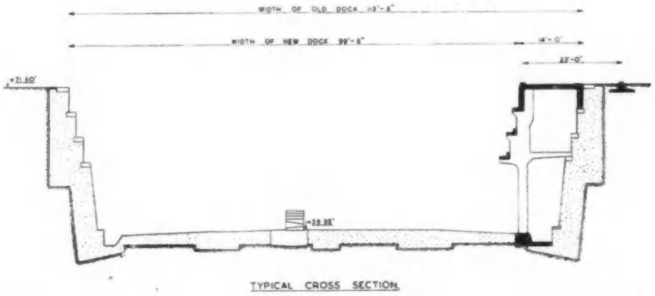


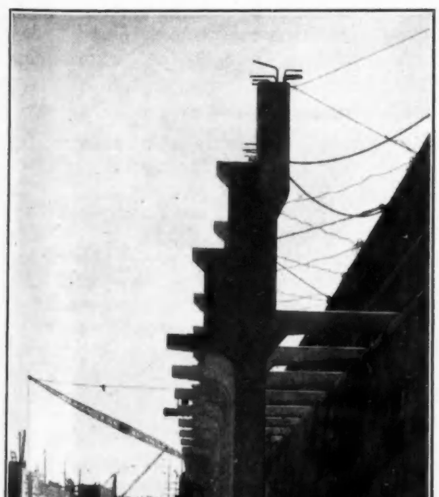
Fig. 1.
Plan and typical cross-section of dock.

width of the entrances has been increased and caisson gates of the increased width are being provided.

The excessive width of the old dry dock intended for the berthing of two ships abreast, is not convenient for berthing single ships, so the dry dock between gates is being narrowed by moving one of the side walls forward, and, of course, the double lines of keel blocks are being replaced by a single line.

The net result of the alterations will be to produce a graving dock of 940-ft. overall length which can be sub-divided by the intermediate gate into two portions the near portion 445-ft. long and the nether portion

Fig. 3.



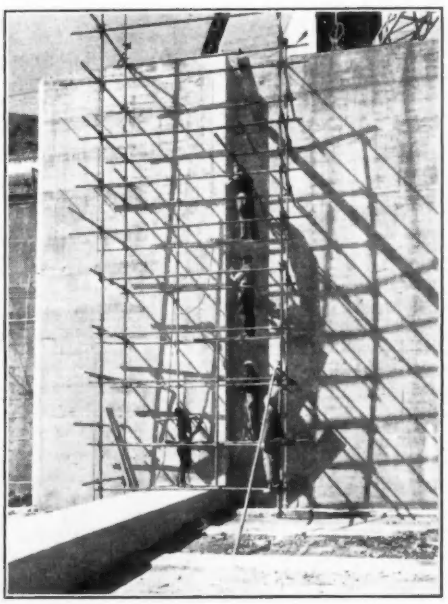


Fig. 4.

477-ft. long. The width of the new entrances is 76-ft. 6-in. at sill level and 78-ft. 6-in. at cope level.

The accompanying plan, which shows the old structure as it was in dotted line with the reconstructed arrangement in full line, illustrates the changes mentioned above, and the accompanying photograph (Fig. 1) taken from a coal tip on the Wet Dock side shows the work of reconstruction now in progress under the protection of a temporary floating dam placed across the outer entrance. The water in the background is the Bristol Channel with the Somerset coast behind.

The two new caisson gates that are being

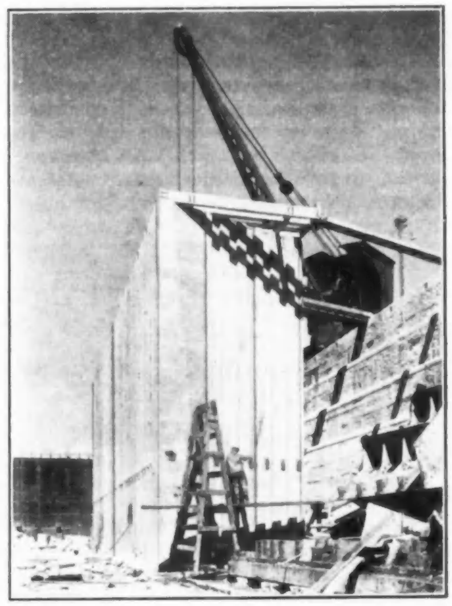


Fig. 5.

built inside the dry dock at the same time as the structural alterations are conspicuous features in this photograph.

In the execution of this project, Messrs. C. H. Bailey were naturally desirous of obtaining the utmost constructional speed together with the utmost economy compatible with the best workmanship. Messrs. Maunsell Posford & Pavry were the Consulting Engineers employed by Messrs. Bailey to achieve these objects and the contract for carrying out the works was awarded to Messrs. John Howard & Co., Ltd., Public Works Contractors.

Among the novel features in the reconstruction programme may be mentioned the setting forward of one of the dry dock side walls by means of mock altars composed of reinforced concrete posts and reinforced concrete steps which stand out 14-ft. clear in front of the old dock wall. The concrete posts are clearly shown in the photograph (Fig. 3). Each of these posts weighs 10 tons and was precast on the floor of the dock in a horizontal position prior to being hoisted into the upright position. The horizontal altar beams had not been erected when the photograph was taken but the three ledges on the posts prepared for their reception are

Reconstruction of Barry Commercial Dock—continued

clearly visible. A heavy precast reinforced concrete beam is designed to run along the top of the posts and the space between the beam and the cope of the old wall behind is to be covered over by a strong reinforced concrete slab. Mounted upon the top of the beam in front and on the top of the old wall cope behind will be a wide gauge crane track to carry a 25-ton crane of the Tower Portal type. Mounted on the concrete slab on a narrower rail track will be another lighter crane which will be able to pass underneath the portal opening of the big crane so as to serve light material in and out of any part of the dock where repair work is proceeding without having its movement obstructed by the big crane, wherever the latter may happen to be standing.

The photo (Fig. 4) shows one of the newly completed meeting faces against which the timber face of the floating gate is designed to press. The granite masons are engaged in putting the finishing touches to the granite face after erection. All the stones used in these meeting faces are some of the original Cornish granite stones taken out of parts of the old dry dock which have been recut and refitted by granite masons specially brought to the site from Cornwall by the granite quarrying firm of A. McLeod & Company. It has been found that the old granite after 50 years' service cuts as cleanly and dresses up as well as if it were freshly quarried, but, in order to economise dressing work and material, it has been found necessary to make a few departures from the time honoured usage customary in this ancient craft.

Apart from granite copes, quoins and altars, the construction of the old dock was a composite one. For parts where heavy stresses were anticipated the original builders had used engineering brickwork and elsewhere they had used a kind of cyclopean masonry, the exposed surfaces of wall being mostly built of roughly dressed sandstone ashlar. The new work which marries up with the old in many places is built mainly in mass concrete supplemented by reinforced concrete and by granite as and where either necessity or economy justified. All the work both old and new is of a very high quality.

The two new floating caisson gates are designed to operate more or less on lines hitherto employed in similar circumstances but owing to special exigences of the case such as difficulties that were anticipated in obtaining early delivery of fabricated steelwork, it was decided to make use of a rather novel form of structural detail construction which combines a corrugated steel outer walling with reinforced concrete inner framing.

The photo (Fig. 5) shows one of these caisson gates in process of building inside and pari passu with the reconstruction of the dock itself. The main Contractors are themeslves successfully carrying out the highly specialised work of building these caissons to the designs of the Consultants above mentioned.

In spite of rather adverse weather conditions during the past autumn, winter and spring, progress has been good and it is expected to have the dock in use for the purpose of dry docking vessels during the present summer.

National Dock Labour Board

Excerpts from 4th Annual Report for the year 1950

The 4th Annual Report of the National Dock Labour Board which was issued early last month shows that during 1950 the average labour force registered with the Board was 75,264 men. Voluntary absenteeism averaged 1.5 per cent. and as many of these absences were afterwards explained, this can be regarded as most satisfactory.

Employment during January, 1950 reached an unusually high level, and daily transfers to augment local labour were heavy. By March, seasonal declines in the volume of traffic passing through the ports became evident and the volume of surplus labour rose steeply, exceeding 9,000 men daily. Thereafter, employment improved, and though the usual fluctuations were apparent, the volume of surplus labour rapidly declined to about 6,000 men a day. In June, in spite of the use of transferred men, shortages of labour caused serious concern, particularly in Liverpool.

During the second half of the year there was a decline in the anticipated timber imports and coal exports which, with troubles in the near Continental ports, affected employment on the docks. The number of men surplus to requirements in some ports, noticeably Hull, Bristol and Cardiff, increased to more than 20 per cent. of the Register; at the same time there was heavy pressure elsewhere and, at the end of November, five hundred men from Hull, Bristol and Cardiff were transferred to Liverpool, where they stayed until Christmas.

At the end of the year, traffic reached extraordinary proportions. In the week before Christmas the surplus labour throughout the country was reduced to 2,500 daily; there were heavy shortages of labour; very many vessels were seriously delayed; fresh arrivals could not dock—for example, at the turn of the year, 22 deep-sea vessels awaited berth in one port alone.

Temporary Registers were set up to meet seasonal and other requirements, and some 11,000 man days were worked by men on period transfer. In addition, men on daily transfer and non-registered labour were extensively employed.

National Agreements governing wages, attendance money and guaranteed weekly payments continued unchanged. The average weekly earnings of daily workers during the year were £8 12s. 10d. compared with £8 8s. 11d. in 1949. In December, last, the National Joint Council agreed with the Board a new form of guarantee to non-registered labour engaged for cargo work.

Welfare and Medical Services

Six new medical centres were opened during 1950—at South Shields, London, Swansea (2), Newport and Barry. There are now 24 Port Medical Centres in fourteen ports. During the year 200,000 treatments were given, of which more than 88,000 were to registered workers. The Rehabilitation Centre at Claremont has been maintained for dock workers from the North of England ports; 350 men were treated at this centre during 1950. In addition, 159 dock workers were sent to other rehabilitation centres.

Six new Dock Workers' Clubs with a membership of 5,280, were opened with funds loaned by the Board. By December, 1950, there were twelve such clubs in existence with some 8,400 members, and outstanding loans amounted to £36,804.

Week-end residential schools for dock workers in five areas were held during the year, and grants in aid were given to seven Liverpool dock workers to attend a fortnight's residential course on Port Working at Burton Manor College, Cheshire. A scheme for the arrangement of evening classes on the same subject has been agreed nationally with the Technical Colleges, the National Joint Council and Port Authorities.

Percentage Payments on Wages

The rates of percentage payments on the wages of daily workers engaged on ordinary dock work remained unchanged during the year at 15 per cent., but after considering representation by the National Association of Port Employers and the Chamber of Shipping, the Board exercised its powers under Clause 21 (2) of the Scheme and, as from 1st July, 1950, fixed a special rate of levy (10 per cent.) in respect of daily workers engaged on coastal traffic as defined in an agreement made by the parties concerned.

No change was made in the rate of percentage payments on the wages of weekly workers, which was maintained at 5 per cent.; and, throughout the year, appropriations from Management Fund to the General Welfare and General Reserve Funds were continued at ½ per cent. on the wages of all workers, and 2 per cent. on the wages of weekly workers respectively.

Because of the high level of employment already referred to, the surpluses on all funds for the year substantially exceeded estimates, and in December the Board announced that, as from the beginning of 1951, the rates would be reduced to:—Normal Daily Workers, 13½ per cent.; Coastal Traffic Workers, 9 per cent., and Weekly Workers, 3 per cent.

Model Studies of Apra Harbour

Carried out by California Institute of Technology in Collaboration with United States Navy Bureau of Yards and Docks

ROBERT T. KNAPP, Director.

(*continued from page 64*)

STANDING WAVE PATTERNS

The phenomenon of reflected surface waves from a steep shore gives rise to standing waves which are at any point the summation of motions of the water particles at that point due to the two waves, the incident wave and the reflected wave. The shore line may be even fairly rough without affecting the reflection, providing the irregularities are small in comparison to the wave length. As the velocities of both waves are equal, where crest meets crest, and trough meets trough, the vertical motion will be accentuated, and when crest meets trough the vertical motion will be cancelled out so that the result is a standing wave pattern, or one that is fixed in position. Since the pattern of the standing wave is determined by the length of the incoming wave train and its angle of incidence with the reflecting boundary, there must be a standing wave pattern associated with each wave length or period component of the incoming wave train.

In any harbour there is a likelihood that there will be two reflecting surfaces opposite each other which will reflect the wave back and forth. For such a system there will be certain wave periods or lengths for which the reflections from the two surfaces, or basin walls, are in phase, with a resulting build-up in amplitude of the standing wave. Thus, any enclosed body of water constitutes a dynamical system capable of oscillating in definite modes at certain natural periods and harmonics thereof, and for typical harbour basins these resonant periods may range from a fraction of a minute to an hour or more. If the period of the imposed long period wave coincides with one of the resonant periods of the basin, the amplitude of water motion within the basin will increase until the rate of friction loss equals the rate at which energy is being added to the system by the incoming wave train.

It is, of course, true that for steady-state conditions the rate of energy dissipation by friction always equals the rate of energy addition. In the general case, the wave continues to propagate, undergoing numerous reflections, until it is damped out. The resulting wave pattern is very complicated, containing many wave crests propagating in many directions. The essential characteristic of resonant oscillation is that because the major reflections match in direction and phase, the entire energy is concentrated in a simple wave pattern containing but a few wave crests.

There is difficulty in calculating the resonant periods of an irregularly shaped basin by analytical methods; however, it is possible to get good approximate values by simple physical reasoning; in a standing wave, the horizontal water particle velocity is zero at the antinodes, or troughs, and crests. Since there can be no horizontal flow at the reflecting boundary, there must always be an antinode of the standing wave pattern at such a boundary. Consider then an idealized case where a wave train is travelling back and forth between, and parallel to, two parallel reflecting boundaries. If the period and velocity of the wave train is such that its wave length is twice the distance between boundaries, then the first crest will reflect from the far boundary and arrive back at the near one at the instant that the second crest reaches this boundary. Thus a standing wave is set up with antinodes (of opposite phase) at the boundaries, which is exactly in phase with the incoming wave train. Since this is the longest period wave which fulfils the boundary conditions, and is in phase with the incoming wave, it is the *fundamental mode* of oscillation of such a basin; the amplitude of oscillation will build up until the damping losses equal the energy added per cycle by the exciting wave train. The fundamental period is therefore that of a wave of length 2 l or $T = 2\,l/c = 2\,l/\sqrt{g\,h}$.

If the wave length of the exciting wave train is equal to the distance between boundaries, the first crest will reach the far boundary at the same time that the second crest enters at the near boundary, and the reflection of the first crest therefore meets and reinforces the second crest at the centre of the basin. This is the first harmonic of the basin, and $L = l$. The second harmonic occurs with a wave length of two-thirds the width of basin ($L = \frac{2}{3}\,l$), the third harmonic with a wave length of half the width of basin ($L = \frac{1}{2}\,l$), and so on. Similarly, for a basin with a reflecting surface at one side and open to the sea at the other, the modes of resonant oscillation are such that there is an antinode at the closed end, and a node at the open end, when the fundamental mode has a wave length of four times the basin width $L = 4\,l$, with first and second harmonics of wave lengths, four-thirds ($L = 4/3\,l$) and four-fifths ($L = 4/5\,l$) of the basin width respectively. In this case an end correction must be applied depending on the relative width of the opening, increasing the periods by 10 per cent. where the width to length of harbour is one-tenth, and 32 per cent. where the ratio is unity.

In a standing wave the amplitude of horizontal particle motion, hence the average velocity, varies from a maximum at nodal points to zero at the antinodes. At a given point in the wave, the water

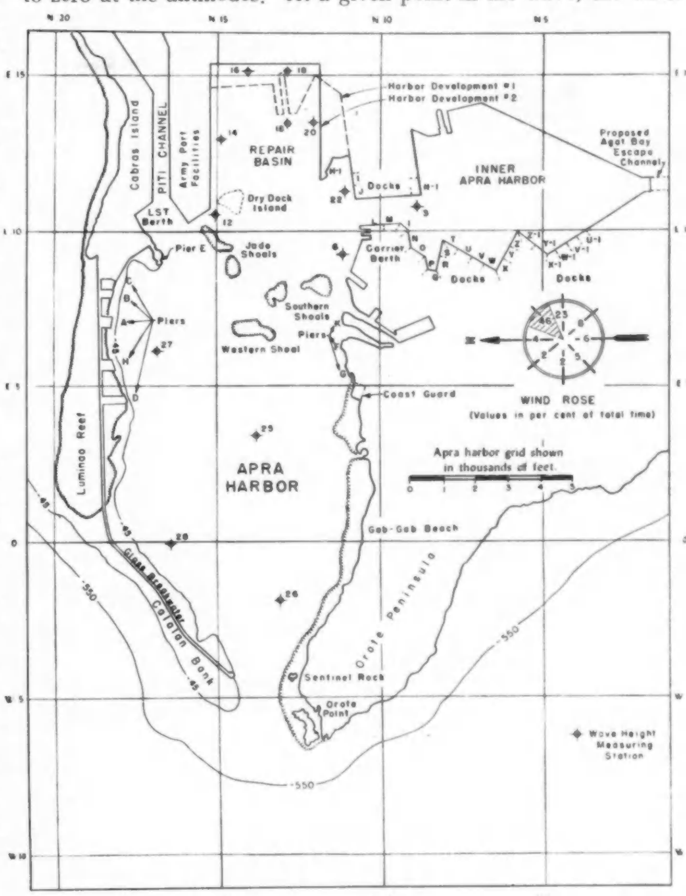


Fig. 34. Map of Apra Harbour, showing wave measuring stations, and alternative development plans of Repair basin.

Model Studies of Apra Harbour—continued

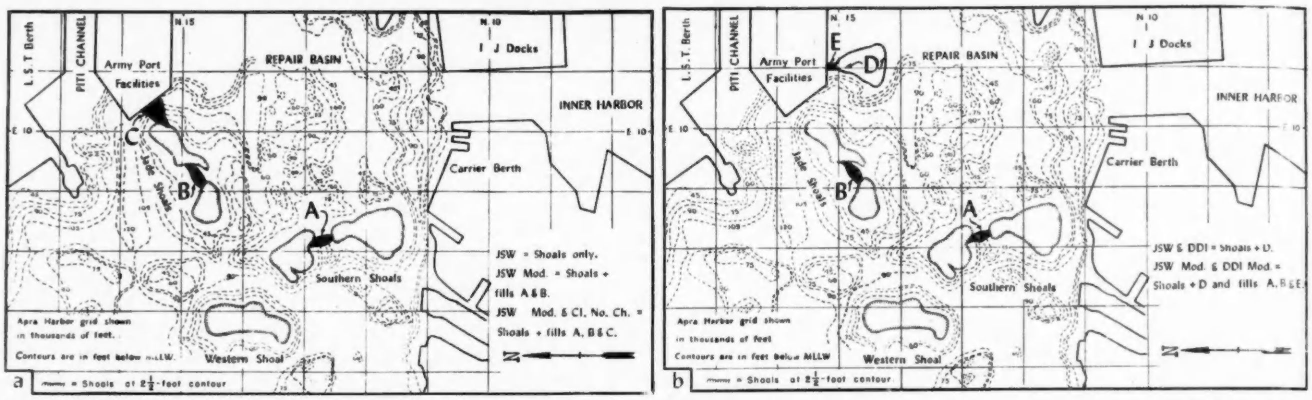


Fig. 35. Details of five shoal plans. JSW, JSW Mod., JSW Mod. and closed north channel (left), and JSW and DDI, and JSW Mod. and DDI Mod. (right).

particles are moving in orbits, hence at time intervals corresponding to the end positions of the orbits the velocity is zero, and at time intervals corresponding to the mid position of the orbits the velocity is a maximum. The integrated horizontal velocity over one wave length is zero, neglecting the small mass transport effect; hence a large harbour structure which may span one or more wave lengths of such a short wave is not affected by the horizontal velocity. For long period surges this is not the case, since the wave length may be several miles long, when the horizontal velocity appears as an oscillating current covering large reaches of the harbour.

The average horizontal velocity at a model section for a shallow water wave is:

$$V = \frac{2h \coth Kd}{T} \quad - \quad - \quad (1)$$

where h = wave height
d = water depth
T = wave period
K = $2\pi/L$
L = wave length.

For small values of d/L corresponding to shallow water waves:

$$\coth Kd = \frac{1}{\tanh Kd} = \frac{1}{Kd} \quad - \quad (2)$$

combining (1) and (2)

$$V = \frac{2h}{KdT} = \frac{hL}{\pi dT} \quad - \quad - \quad - \quad (3)$$

Since the motion is sinusoidal, the maximum velocity is equal to $\pi/2$ times the average, or:

$$V_{max} = \frac{hL}{2dT} \quad - \quad - \quad - \quad (4)$$

also, since $L/T = c$, the wave velocity and $c = \sqrt{gd}$

$$V_{av} = h/\pi \sqrt{g/d} \quad - \quad - \quad - \quad (5)$$

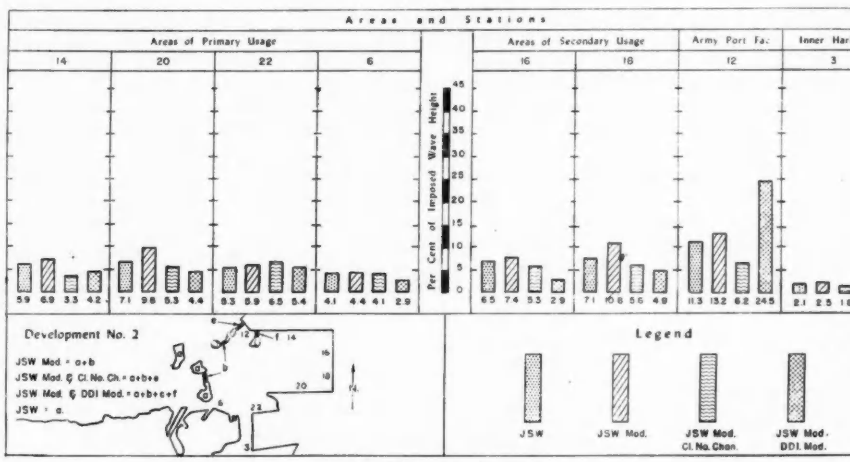
and

$$V_{max} = h/2 \sqrt{g/d} \quad - \quad - \quad (6)$$

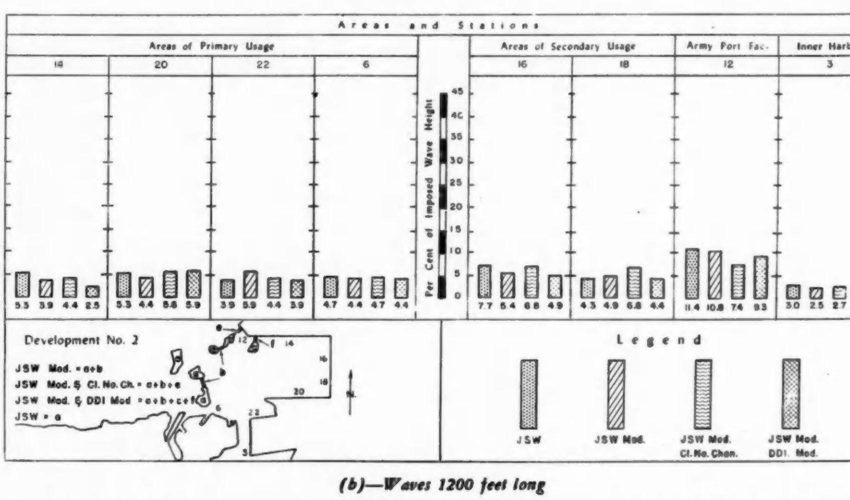
Thus the horizontal water velocity is dependent on the wave height and the water depth only, and will therefore have the same magnitude for a given harbour depth and wave height, regardless of wave period or length. A further important consequence of this line of reasoning is that the horizontal displacement of the water particles is directly proportional to the wave period, since the displacement is the product of the average velocity and half the wave period.

INNER HARBOUR. REDUCTION OF DISTURBANCES

For the following tests the outer harbour was protected by the breakwater type D with the head of type D. The model was undistorted to a scale of 1/360 and situated at Azusa (Fig. 34).



(a)—Waves 600 feet long



(b)—Waves 1200 feet long

Fig. 36. Effectiveness of four shoal plans. Westerly waves, 30 feet high. MLLW.

Model Studies of Apra Harbour—continued

The purpose of these experiments was to investigate what improvements, if any, were to be achieved by dredging the shoals to minus 45 feet, and also to determine if conditions in the usage areas would be bettered by the provision of inner breakwaters which were to be founded in major parts in water not deeper than 45 feet below M.L.L.W. The main shoals, Jade, Western and Southern, form a natural though broken boundary between the outer harbour and the usage areas, repair basin, and inner harbour. The elevation of the tops of the shoals is, on the average, minus 2.5 feet below M.L.L.W. The preliminary tests were concerned with various different forms of linking up, and removal by dredging, of these separate shoals. There were nine different

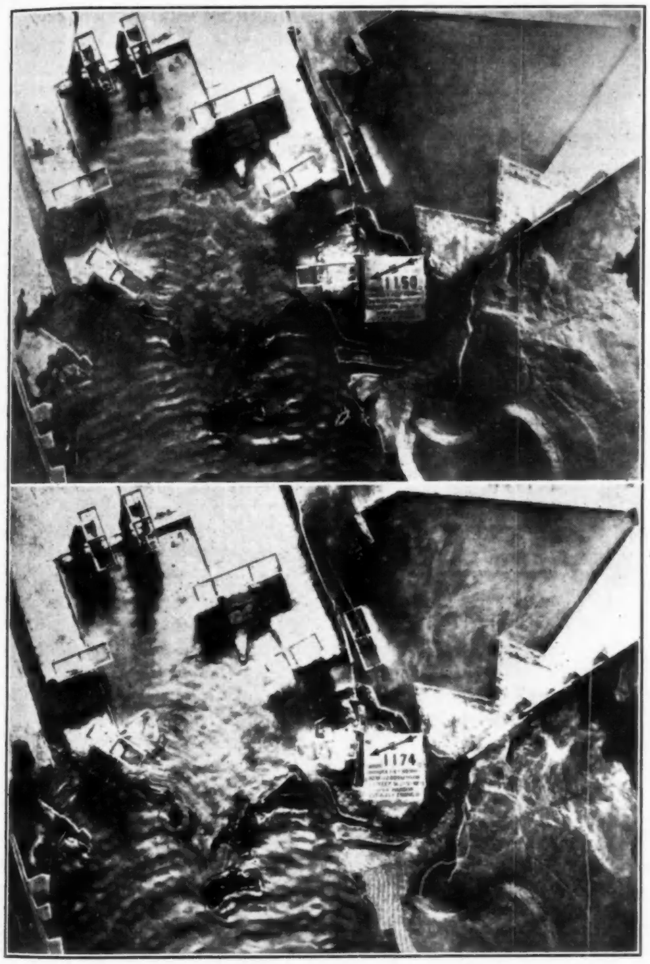


Fig. 37. Plan JSW, above, and JSW Mod. and DDI Mod., below, disturbances in the Repair basin. Westerly waves 30 feet high, 1,200 feet long, MHHW.

forms and all were tested under high and low water conditions; the tidal range being computed at 2.3 feet. The linking up between two separate shoals was effected by fill to level −2.5 feet in all low gaps.

It will be appreciated that within the harbour, after an initial transient period, the average rate of energy dissipation must equal the average rate of energy transfer into the harbour, and therefore steady-state conditions do obtain on a long time average basis, although it is still possible for the disturbances at particular points to vary with respect to time. Thus at any point within the harbour the water surface disturbance at a given instant is the resultant of a large number of waves, one directly imposed from the ocean, and many others the results of reflections of previous waves, which reach the point at the given instant. Therefore the further within the harbour the less the influence of the ocean wave, and the greater the influence of the reflected waves. There is one feature of significance arising from this. Since the number of possible paths for reflected waves in a basin, such as the repair basin, is large, and since even a single reflecting boundary may act as a source for several such paths, the basin is analogous to a mechanical system of many degrees of freedom with loose coupling between the modes. For such a system there will always exist the phenomenon of energy wandering between the modes.

The effect of this wandering of energy in the repair basin was observed in the experiments as a shift in the over-all disturbance pattern, as a variation in the magnitude of the disturbance at particular points during a run, and by the variation in average

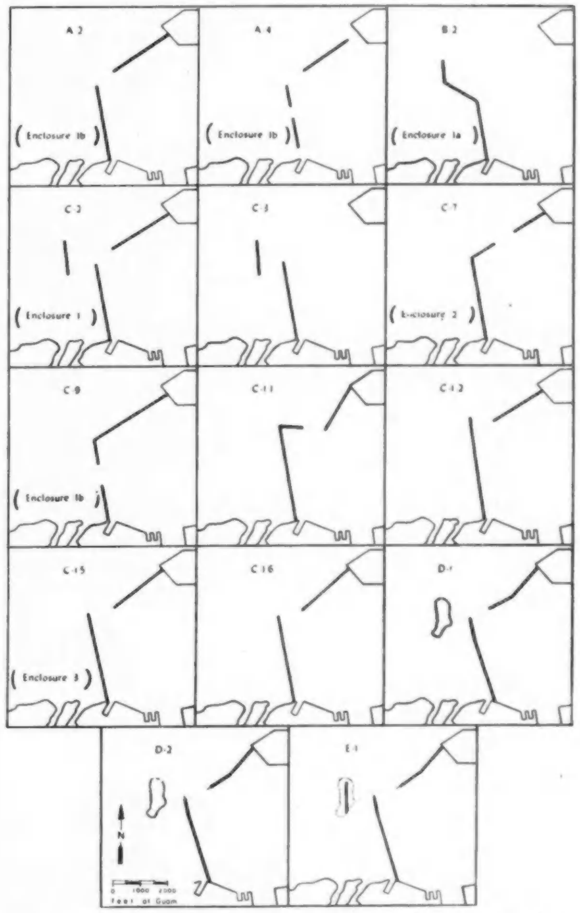


Fig. 38. Schematic outlines of the main inner breakwater plans.

and maximum disturbance measurements for a particular point from duplicate observations. Such duplicate observations indicated that for a six minute sampling interval the measured disturbance at a point is subject to a variation of 14 per cent. It was estimated that one-third of this was due to appliances, etc. This essential hydrodynamic instability of the disturbance pattern is not a fault of the model, but is a physical phenomenon which limits the applicability of the measured data to the evaluation of the various harbour structures. The instability is local in character, and true steady-state conditions do obtain on the basis of the integration of disturbances over large values of space and time.

At first, wave height measurements were made for only 20-second periods, but later it was found that a six-minute test run was needed, and this was adopted as standard. This was the length of recording time at each element array station for a given wave condition and project. To ensure correct wave height measurements in this area subject to the influence of standing waves, in place of single elements to measure the wave height at any one place an array of 16 were placed on a 12-inch square

Model Studies of Apra Harbour—continued

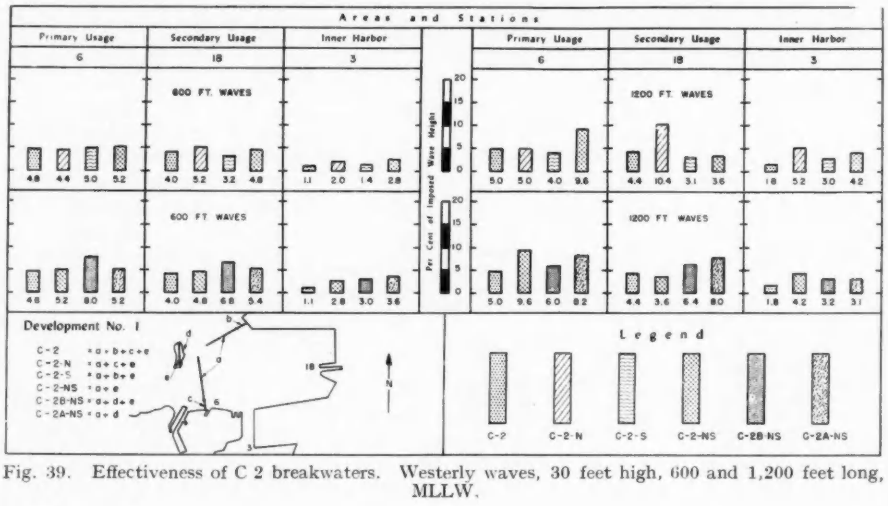


Fig. 39. Effectiveness of C 2 breakwaters. Westerly waves, 30 feet high, 600 and 1,200 feet long, MLLW.

frame; each element spaced 4 inches from the other, that is, at the corners of 4-inch squares. This eliminated all uncertainty, as the sixteen records covered an area 360 feet square, in which maximums and minimums were measured.

Five of the nine different combinations of the existing separate shoals and the test designations are shown in Fig 35. The deep black portion shows the position of the fill to link up the separate portions. One of the conditions was to provide an entrance of 750 feet minimum width with a minimum depth of 45 feet below M.L.L.W. All tests were carried out with westerly ocean waves 30/600 and 30/1200 heights and lengths respectively. The two projects D.D.I. and No Shoals include the dredging of all shoals to the minimum depth.

A typical graphic diagram of the test runs is shown in Fig. 36 and the corresponding shoal plans in Fig. 35. The legend attached to each is sufficiently explanatory. Photographs were also taken simultaneous with the observations, Fig. 37 being typical. The following table gives a few of the comparative disturbances in the repair basin and represents the average at wave height measuring stations 14, 20, 22 and 6, also known as Primary Usage area.

Shoal Plan	Maximum disturbance in per cent of imposed wave height M.L.L.W. 600 feet	M.L.L.W. 1200 feet	M.H.H.W. 600 feet	M.H.H.W. 1200 feet	average disturbance	Per cent of disturbance compared with that of shoal plan J.S.W.
1. JSW MOD & DDI MOD	4.2	4.2	5.6	7.6	5.4	83
2. JSW MOD and Closed North Channel ...	4.8	4.8	6.6	5.6	5.4	83
3. JSW MOD ...	6.8	4.6	4.9	8.0	6.1	94
4. JSW & DDI ...	4.5	5.5	7.2	8.6	6.4	98
5. JSW	5.6	4.8	5.4	10.2	6.5	100
6. No Shoals ...	33.3	30.9	30.3	36.3	32.7	504
7. DDI Only ...	38.6	38.5	41.8	42.5	40.3	622

INNER BREAKWATERS.

No less than 59 different breakwater plans were tested for the protection of the inner harbour. The main comparative alignments and experiment designations are shown in Fig. 38. All of these breakwaters are sited in the near neighbourhood of the existing shoals. The models were made of concrete with side slopes of $1\frac{1}{2}:1$ to a height of 10 feet above M.L.L.W. and a top width of 30 feet. This height proved to be inadequate to prevent overtopping under typhoon waves, and the breakwaters were raised to a height of 40 feet.

The breakwaters of the C2 series showed more promise than many of the other variations tested, and average results are shown in Figs. 39 and 40. It will be noted that the north opening (b) has an adverse effect upon the tranquillity of the basin even when in combination with the south opening (c). It was noted that higher disturbances result when a breakwater is constructed on the existing undredged Western Shoal than when it is placed on the shoal site after dredging to minus 45 feet. The removal of the breakwater from the undredged shoal increases local disturbances in three out of six cases, although the average is not affected. Lengthening and shortening the breakwater caused no appreciable differences in the repair basin. Breakwaters C2S and C2N were the most and least effective plans of this series respectively. The C7 series, or group, which had the main entrance located in the middle of the northern arm over the Jade shoal, showed the greatest disturbance when the north passage (b) was opened. When the north passage was closed and the south passage (c) was opened, there was more disturbance than with the main entrance only, but less than in the former case; yet when both passages were open, the disturbance was less than with either one only.

The C15 group did not show favourable results, with the exception of model C15A, which was C15 with the presence of the undredged Western shoal outside the entrance. This showed great improvement on the rest of the group, and in addition to less disturbance it gave an almost placid surface of calm in the repair basin for three-fourths of the run time. There was no calm period observed with C2S. Of the C12 group, it was further observed that the performance was not improved by the addition of the undredged Western shoal (Model C12A); in fact, the disturbance was increased by 12 per cent. The probable cause of this was the diffraction of the waves by the Western shoal, so that the wave crests swung more nearly parallel to the entrance.

The considerable adverse influence of the north passage (b) between the Jade shoal and the Army Port Facilities led to the probability that the cause was due to the reflection of the waves by the outer bulkheads of the tip of the A.P.F. It was therefore decided to test a model in which a portion of the tip of Army Port Facilities was removed so that the shore line and the breakwater face presented a straight line. The breakwaters used were of C16 group. The results of the comparisons were disappointing and no support was given for the hypothesis above; it was more likely that the source of the added energy entering by the north channel was reflected from more distant parts of the harbour, and the increased disturbance of 52 per cent. for the model C16 AN showed that the A.P.F. projection was advantageous.

Several variations of the D groups of breakwater models were tested, and it was found that in the repair basin the maximum disturbances were the least in D2S, that is, with the main entrance and the south channel open, followed by D1 with both north and south channels open, and E1 which is D2 plus a breakwater on the Western shoal covering the entrance. This group of breakwaters reduced the disturbances of the J.S.W. shoal conditions by 50 per cent. on the average.

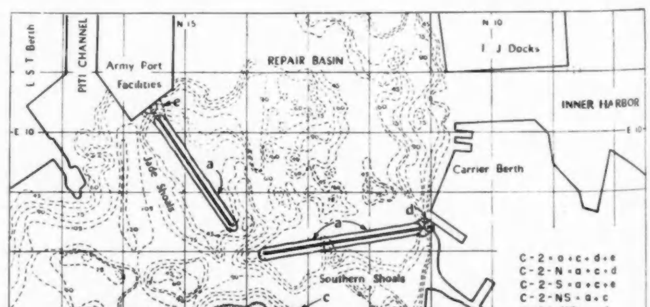


Fig. 40. Details of C 2 breakwaters.

Model Studies of Apra Harbour—continued

SUMMARY.

Considerably less energy entered the repair basin and the inner harbour when Jade, Southern and Western shoals remained undredged with the tops at minus 2.5 feet than when dredged to minus 45 feet. Filling the passages between the shoals to minus 2.5 feet level increased the protection to the repair basin. The magnitude of this improvement was more noticeable near to the shoals than at a distance away due to the irregular energy transfer along the shoals. Generally the repair basin disturbance condition was improved when both the north and south passages were closed. The greater adverse effect of the north passage compared to the south passage was due to the energy set of the harbour waters being north of east and not south of east, or east. In most cases, when both of these openings were used together, the resulting disturbance was intermediate to those with either the south or the north opening alone. In deep water the small tidal range of 2.3 feet made no difference in the resulting disturbances. In passing over the shoals, however, the water depth was doubled at the crests and therefore, as would be expected, the disturbance was increased at high water. Hence for the shoal plans, both water levels were investigated. It was also found in these cases that the disturbance was considerably increased at high water by the longer wave length of 1,200 feet as against 600 feet.

A comparative table of the shoal and breakwater plans is shown below, from which it will be seen that the breakwater plans are more satisfactory than the shoal plans. However, the recommendation of the Laboratory was that no inner breakwater be built and that the Western, the two Jade shoals, and the two Southern shoals would provide suitable protection. Economic construction considerations entered into the deliberations in arriving at this conclusion.

AREA OF PRIMARY USAGE.

Model Designation	Maximum Disturbances in per cent of Imposed wave height — Length of Waves 600 feet	1200 feet	Average	Disturbance compared with that occuring with shoals JSW per cent*		Water Level*
D.2.S	3.1	3.2	3.2	41		H.
D-1	5.0	2.0	3.5	45		H.
E-1	4.7	2.3	3.5	45		H.
C-16A	2.2	3.0	2.6	50		L.
C-12	5.2	3.2	4.2	81		L.
JSW MOD and ...	4.2	4.2	4.2	81	82	L.
DDI MOD ...	5.6	7.6	6.6	84		H.
JSW MOD and ...	6.6	5.6	6.1	78	85	H.
Closed N Chain ...	4.8	4.8	4.8	92		L.
C.2.S	5.0	4.0	4.5	86		L.
C.7	4.0	6.2	5 1	98		L.
JSW	5.6	4.8	5.2	100	100	L.
	5.4	10.2	7.8	100		H.

*Percentages given on corresponding tide levels of JSW — H = MHHW and L = MLLW.

When the large scale undistorted model at Azusa was completed, the preliminary runs were made for the purpose of comparison with the small scale distorted model at Pasadena. The photographic records (Fig. 41) show that there is exceedingly little qualitative difference, and records of the outer harbour disturbances of either model could be used interchangeably. After a continuous run of 14 hours model time, the data for the chart (Fig. 42) was obtained and plotted. This shows the maximum vertical disturbance that may occur in the outer harbour, due to ocean westerly waves 30 feet high and 1,200 feet long. Comparison of the two scale models showed that results agreed to within 14 per cent. The disturbance chart of the outer harbour shows that with the exception of an area swept by the centre portion of the incoming wave crests, the highest waves had a height of less than 33 per cent. of the imposed wave height. One should note the zig-saw puzzle distribution of the disturbances not only within the harbour, but in the immediate offing. Waves with heights of less than 8 per cent. of the imposed wave height were observed east of a boundary formed approximately by Jade, Southern and Western shoals. Other areas of smaller extent having the same maximum height of wave of 8 per cent. were noted in the vicinity of Piers A, B and C, and near the south shore in various places. The greater part of this shore and in patches on the lee side of the main breakwater, from breakwater stations 0 to 50, were subjected to a maximum wave height of 8-17 per cent. of the imposed wave height. No measurements were taken over the shoals and reefs within the harbour, as the water was not deep enough to submerge the measuring elements. In an area of the outer harbour enclosed between the co-ordinates N 13,500 and N 15,700, the disturbed wave height varies between 33-50 per cent. with scattered areas of up to 67 per cent., which makes the area entirely unsuited as a roadstead during storm conditions. This zone of rough water lies further to the north in front of the Piers A, B, C and E, and unfortunately envelopes the tip of Pier E.

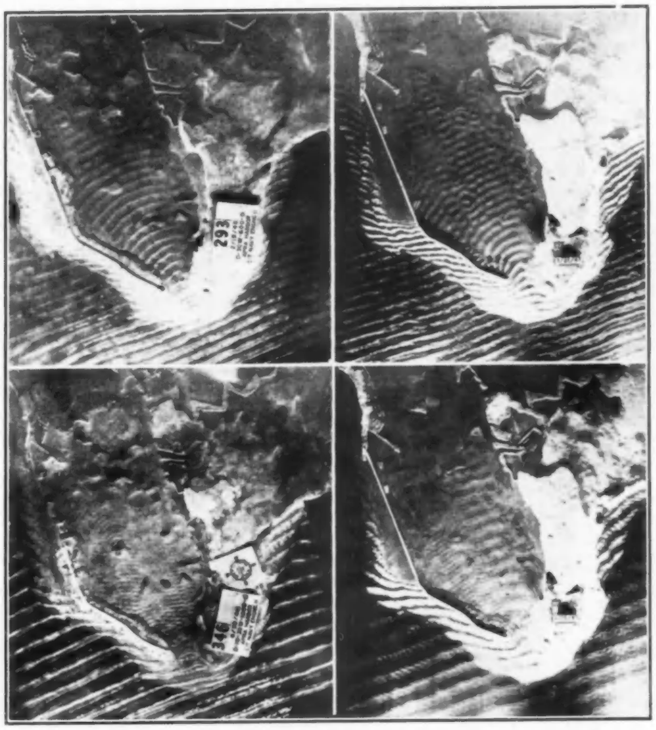


Fig. 41. Comparison of pattern due to westerly waves 30 feet high, MLLW, for distorted models. Photos to left (1/480 vert., 1/960 horiz.) and undistorted models to the right (1/360). Top, 600 feet long waves. Bottom, 1,200 feet long waves.

The chart unmistakeably shows that the north-east corner of the outer harbour is not suited for moorings during westerly storm conditions. It is probable that this large disturbance is partially caused by the incoming waves being reinforced by reflected waves from the harbour confines.

A very interesting observation during the runs was the large number of scattered areas of the ocean where the wave heights exceeded the imposed wave height by up to 35 per cent., due perhaps to reflections from the shore line.

A point of great importance in reduced model experiments arose in the Report regarding quantitative measurements on different models, that the following comparison is of great value. Whilst the data for the two tests are not strictly comparable, they show the essential points. The wave disturbance chart of Fig. 42 was obtained from the small scale distorted model data compiled from the measurements on a grid system with spacing between the elements equivalent to 200 feet; whilst the data for the five stations on the large scale model were obtained by means of the square grid array of 16 elements with a spacing between them equivalent to 90 feet, and further, the test on the small scale model was made at M.L.L.W., but on the large scale model at M.H.H.W. The following table shows the comparison of maximum wave heights in the small distorted scale model and large scale undistorted model, with westerly waves 30 feet high and 1,200 feet long.

Model Studies of Apra Harbour—continued

Location Station	Wave Height in per cent of imposed wave height Small Scale Model	Large Scale Model	Arithmetic mean	Deviation from mean per cent of mean
6	12	10	11	9.1
25	42	70	56	25.0
26	25	107	66	62.0
27	42	48	45	6.8
28	42	93	68	36.8

This table shows poor agreement at three stations, but such divergence cannot be traced to tidal differences, though it may be partially due to the calibration of the measuring elements. In this connection, it is fair to add that methods of calibration in the larger scale model were much improved from the early tests of the small scale model.

There is, however, another important factor to explain the noticeable discrepancy, that of the model scale distortion. With the undistorted model the waves are shallow water waves, scraping the bottom as in the prototype, while in the distorted model the waves act as deep water waves. Whenever a wave passes over a shallow region, the wave length decreases, as can be seen from the fundamental relationship of wave length, wave velocity, and depth:

$$c = \sqrt{gd},\ L = CT, \text{ where } T = \text{constant}.$$

Furthermore, it can be assumed that the energy E, between adjacent areas, remains constant, and from $E \propto wLh^2$ it follows that a decrease in wave length must be accompanied by an increase in wave height. Therefore higher disturbances should exist in shallow areas of the undistorted model than for the relatively deeper corresponding areas of the distorted model.

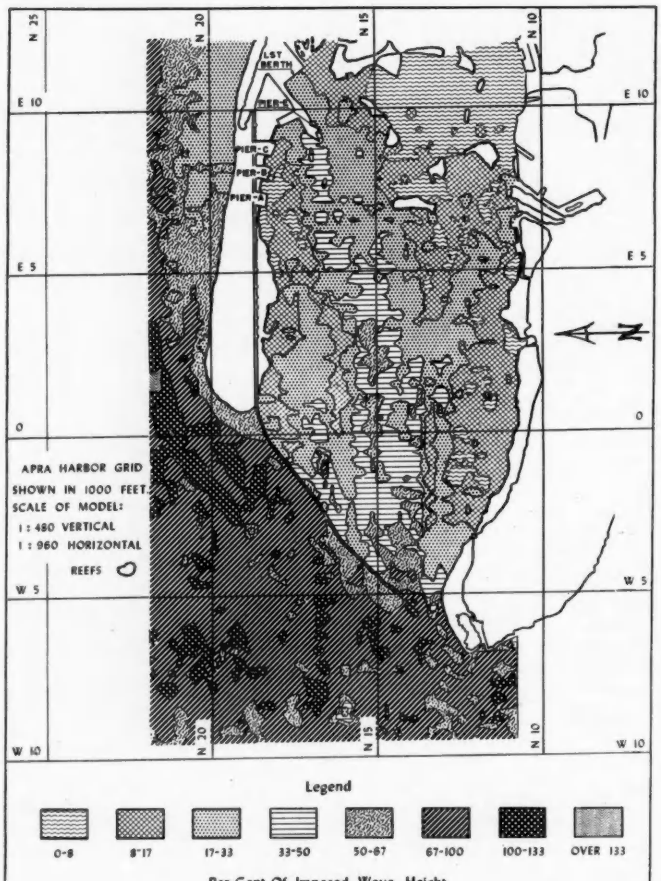


Fig. 42. Maximum vertical disturbances recorded by means of wave height measuring elements on distorted scale model with westerly waves, 30 feet high, 1,200 feet long, MLLW.

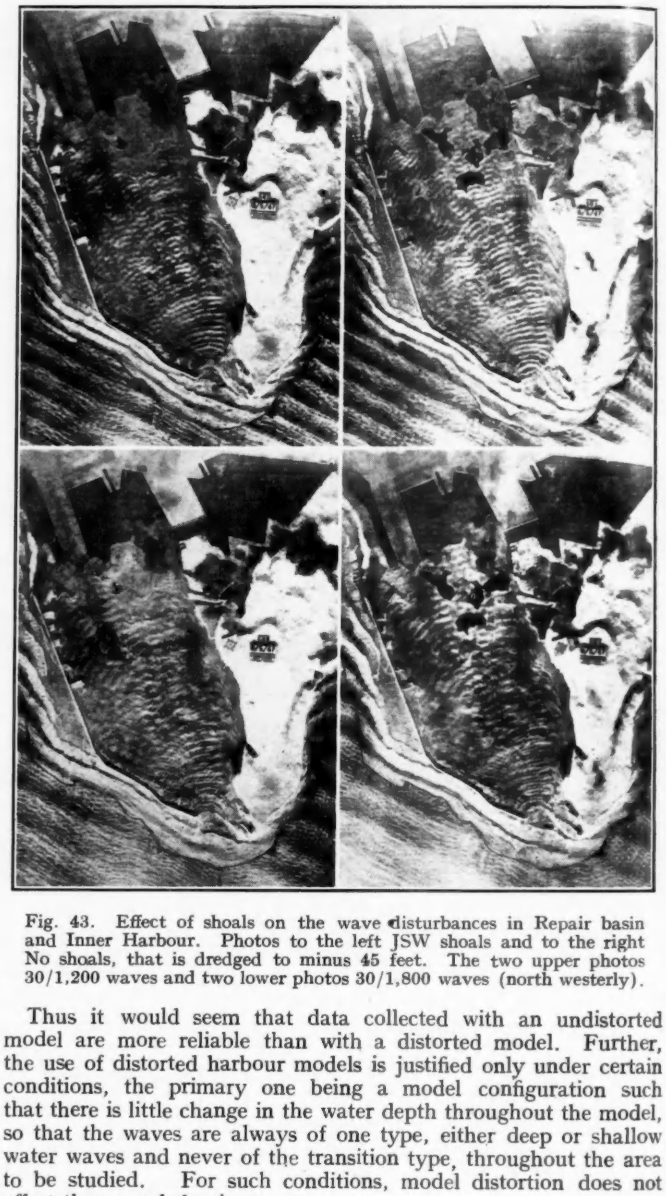


Fig. 43. Effect of shoals on the wave disturbances in Repair basin and Inner Harbour. Photos to the left JSW shoals and to the right No shoals, that is dredged to minus 45 feet. The two upper photos 30/1,200 waves and two lower photos 30/1,800 waves (north westerly).

Thus it would seem that data collected with an undistorted model are more reliable than with a distorted model. Further, the use of distorted harbour models is justified only under certain conditions, the primary one being a model configuration such that there is little change in the water depth throughout the model, so that the waves are always of one type, either deep or shallow water waves and never of the transition type, throughout the area to be studied. For such conditions, model distortion does not affect the wave behaviour.

The disturbance of the water surface in the repair basin is more pronounced when the group of shoals have been dredged to minus 45 feet and the oncoming waves are westerly (Fig. 43). Generally the disturbance in the harbour is increased when the height of imposed waves is increased for any wave length or direction of approach. The effect of change of wave length with a given height cannot be expressed readily in general terms. Westerly waves, 30 feet high, cause the greatest disturbance when 600 feet long, with the disturbance progressively decreasing with an increase of wave length. North-westerly waves, 30 feet high, cause greatest disturbance when 1,200 feet long, with lesser disturbances for the 600 feet and 1,800 feet lengths. The influence of the direction of the oncoming waves upon the alignment of the wave fronts in the harbour is insignificant; with westerly waves the harbour wave pattern is more or less concentric about the entrance, but with north-westerly waves there is a slight distortion (Fig. 43); further into the harbour, differences disappear. This seems to indicate that the harbour entrance channel is the ruling factor. These wave patterns are not permanent, but are subject to cyclic variations.

R.R.M.

(To be continued)

Festival of Britain Engineering Conference

Summaries of Papers of Maritime Interest

To mark the occasion of the Festival of Britain, a Joint Engineering Conference was held by the Institution of Civil Engineers, the Institution of Mechanical Engineers, and the Institution of Electrical Engineers, from 4th—15th June, last.

The object of the Conference was to place on record the contribution to the advancement of civilisation made by the engineers and scientists of this country during the past hundred years, and the interdependence of all branches of engineering, and the ever-growing co-operation of the members of the three major Engineering Institutions in Great Britain, was emphasised throughout the meetings. Papers were presented in abstract so that the major portion of each session could be devoted to discussion.

The Conference was opened at the Institution of Civil Engineers, Dr. W. H. Glanville, President of that Institution taking the Chair. At the opening ceremony, Mr. R. R. Stokes, Lord Privy Seal, said that the vista opened before them as a result of the achievements of engineering was formidable and attractive; it might be the basis for the salvation of the masses of the world, or might lead to ultimate disaster. He was looking to engineers to help the country overcome difficulties created by material shortages. We wanted alternatives to materials now in short supply. Many raw materials, especially the more precious metals, would not be plentiful for a long time.

Throughout the Conference, simultaneous technical sessions were held at the three Institutions, and papers were presented on railways, sea transport and electrical power generation. A synopsis is given below, of those papers which are likely to interest readers of this Journal.

Ports and Harbours

By Leopold Leighton, O.B.E., M.I.C.E., M.I.Mech.E., A.M.I.E.E.

This paper dealt in general outline, with the development of the lay-out of the water areas, quays and so forth of Ports and Harbours, since the making of the first wet-docks in the early years of the 18th century. The great and increasing importance of the rapid and economical handling of ships, with their inward and outward cargoes, has directed the trends, both of the design and equipment, of present-day Ports and Harbours and of the modification of the older ones.

Reference is made to the importance of power-operated machinery for the many items of mechanical equipment and plant essential at a modern Port. From 1846, hydraulic power, as did steam, played a leading part in the development of such machinery. In recent years, the large-scale adoption of electric power has been brought about by its many advantages. This form of power is, to-day, vital to the many types of cargo-handling machinery so necessary for dealing rapidly and, therefore, economically with the many and varied types of cargo.

The importance of harbour facilities to Great Britain is reflected by the fact that there are to-day in this country 330 ports, operating under statute, ranging from large passenger and cargo ports to small fishing harbours and harbours of refuge. Of these undertakings, 50 are now controlled by the British Transport Commission, 110 are administered by Harbour Boards Commissions or Trusts, 70 are owned by Municipal Authorities, and 100 by Companies or Individuals. In addition, there are the naval ports and dockyards.

In a large port system, dredgers may have to deal with a million tons of silt a year. Considering the matter on the bed of the seas which is agitated by storms and carried by the great tidal impulses, it seems that some dredging will always be necessary. Even with natural depths adequate for shipping, it is only necessary to study what happened to the ancient ports of the Mediterranean to appreciate the result when artificial means are not adopted to counteract the natural deposits; and there are examples in this country of what were once navigable waterways which are now of little if any value commercially.

Generally speaking, a Port Authority is fully occupied in providing berths and ensuring that the port system will operate efficiently without undertaking warehouse duties, with the one important exception of grain; during the five years 1934-38, some 180,000 tons of grain per week were imported into this country, where the largest silo has a storage capacity of 60,000 tons and a pneumatic plant able to discharge ships at the rate of 600 tons per hour. Engineers have contributed greatly to mechanical handling of bulk cargoes like grain, seeds, coal, ores, petroleum, molasses, latex and sugar.

Dry Docks

By J. Guthrie Brown, M.I.C.E.

The evolution of dry docks from ancient times up to the present day is traced in outline in this paper, the modern requirements for dry-docking ships are summarised, and finally, the probable trends in dry-dock design to meet the anticipated requirements of future ships is dealt with.

The historical treatment describes early primitive dry-docking facilities and shows how they developed throughout the world with the expansion in size of sailing ships, and finally the manner in which the number and dimensions of dry docks increased, particularly in Great Britain, during the 19th century.

A comparison is made of the leading dimensions of the world's modern major dry docks, and it is shown how the proportions and size of dry docks during the 100 years preceding 1940 have kept pace with the requirements of ship design. The methods adopted in modern dry-dock design to simplify construction, thereby counteracting the high cost of the numerous services and equipment with which modern dry docks must be supplied, are dealt with at some length.

In considering the probable developments of dry docks, conclusions are drawn from the present trends in design of commercial and naval vessels, and the probable effect these tendencies may have on the dry docks of the future is discussed.

There are 32 major dry docks in the world ten of them within the British Commonwealth, and so well distributed that they might be considered as capable of serving most of the world's main sea routes. Ten are situated around the seaboard of the United States; of the remaining nine docks, eight are in Europe and one in the Panama Canal Zone. Any forecast of dry docks of the future is linked to the gradual increase in the dimensions of the vessels now building or projected. General average increase in the size of commercial vessels, and particularly the increase in their beam in proportion to their length, continues. In considering the more distant future developments of dry docks, atomic power and the atomic bomb cannot be ignored. The future impact of these momentous discoveries upon both naval and commercial vessels is a problem to which at present no definite answer can be given.

Applications of Electricity to Sea Transport

By Sir Archibald J. Gill, B.Sc. (Eng.), President I.E.E.

The paper begins with a brief introduction giving the history of the early application of electricity to ships, and this is followed by four sections covering communication services, navigational aids, auxiliary services and electric propulsion.

The first and second Sections are given longer treatment than the others, as electricity is an essential medium for communications and navigational aids, whereas, for auxiliary services and propulsion, electricity is an an alternative to other means of operation.

The development of the United Kingdom ship-shore radio services, and the present world-wide organization of British Commonwealth maritime services, are outlined. Typical kinds of ship's equipment are described, and a brief reference is made to harbour services using waves in the metre band. Navigational aids discussed are direction-finders and radar. Recent developments in the use of shore-based direction finders are mentioned.

Various systems—electrical and otherwise—in use for auxiliary services are discussed, and an indication is given of the relative trends in the supply of electrically — and steam-driven deck machinery. It is probable that there will be an extension of the use of alternating currents for auxiliary services.

The various methods of electrical propulsion are briefly mentioned, and the advantages for special purpose vessels of a system with Diesel-driven generators is emphasized.

The first use of electricity on board seagoing ships was for electric lighting, and probably the earliest installations were in

warships for the operation of searchlights in about 1875, later extended to the internal lighting of ships.

In 1900 a practical system of wireless telegraphy was developed for use on board ship, and this stimulated the further use of electricity, which also applied to such purposes as the driving of fans, passenger lifts, winches, windlasses, capstans and pumps in connection with electro-hydraulic steering gear, the first example of which was installed about 1911. The first use of electric power for ship propulsion dates back to 1839, when a Russian scientist named Yakobi equipped a small boat at St. Petersburg with an electric motor fed by a battery of Grove cells. The first serious use appears to have been in submarines from 1886 onwards, while the first application to a merchant vessel was in Russia in 1903, when the shallow draught tanker *Vandal* was equipped with three oil engines each driving a dynamo and exciter; each dynamo normally energized a separate propulsion motor driving its own screw. Means were available, however, for interconnecting dynamos and motors. The first British built commercial ship to be fitted with electric propulsion was the *Wulsty Castle* completed in 1918 and fitted with steam turbo-alternators and induction motors, followed in 1921 by the fruit carrier *San Benito* equipped with a turbo-alternator driving a propulsion motor of 2,500 shaft horsepower. Since then, appreciable numbers of British ships have been equipped in this way.

Until the introduction of radio aids, navigators were able to determine their position only by astronomical observations or by taking compass bearings of fixed, visible objects. It is unlikely that for many years to come ocean-going vessels will be under continuous radio cover, while in very confined waters it may be that radio instruments will never prove to be satisfactory substitutes for local pilots. Nevertheless, radio aids are proving to be of increasing value, particularly to coasting vessels under conditions of poor visibility and in situations where the ship may be endangered by unpredictable drifts due to tidal streams, currents or wind. The saving of ship's time with radio aids will often more than cover their cost, and by using radar a cable ship stationed in the inner harbour at Dover was able to leave the harbour and then proceed under guidance of the Decca navigator to a position where a fault in the cable was believed to exist. The faulty portion was identified and repaired and the ship returned to harbour all within a few hours.

Mechanical Engineering in the Mercantile Marine

By T. A. Crowe, M.Sc., M.I.Mech.E.

The paper commences with a brief account of the state of development of mechanical engineering in ships in about the year 1851. The history of the reciprocating steam engine is then traced through its various stages, e.g. paddle engines, screw engines, simple- and multi-expansion engines. Reference is made to the coming of the steam turbine and heavy oil engine.

The second portion of the paper covers the present position of the reciprocating steam-engine, the steam turbine and reduction gearing, the heavy-oil engine, and the gas turbine, and an attempt is made to deduce the reasons for the various developments which have taken place.

In the third and final section the author endeavours to forecast future developments, and gives a brief examination of the possibilities of using nuclear energy for the propulsion of ships.

"Engines and machinery, liable to many accidents may fail at any moment, and there is no greater fallacy than to suppose that ships can be navigated on long voyages without masts and sails." This quotation from the naval "Seamanship Manual," published about a century ago, shows briefly the position of marine engineering at that time. When the proportion of steam tonnage to sailing tonnage was small. In 1849 steam vessels owned in Great Britain amounted to only 170,000 tons compared with approximately 3,000,000 tons of sailing vessels. In 1866 comparative figures were 747,000 tons of steam vessels and 4,705,000 tons of sailing vessels. It was not until after the compound engine had been generally adopted in the 1880's that steam tonnage in British ownership exceeded sailing tonnage. Before this occurred, the sailing vessel remained the most economical means of carrying large cargoes for long distances.

The reciprocating steam engine reached its zenith in 1902, when the construction of mammoth engines marked the high water mark of mechanical engineering. In 1884 Sir Charles Parsons patented his reaction steam turbine, and in 1894 built the first vessel ever to be propelled by steam turbines. With these, the vessel reached a speed of 34½ knots of the fastest reciprocating-engined destroyer of that time.

The author said that in his opinion the steam turbine is likely to remain unchallenged for the propulsion of large passenger liners, or for any vessel requiring more than 10,000 to 12,000 horsepower per shaft. In the last decade the gas turbine has made rapid advance in the air and on land, and it is only a matter of time before it is used in the mercantile marine. The design of a gas turbine for a merchant ship would be based more on that of industrial gas turbines than on aircraft gas turbines.

In considering atomic power, Mr. Crowe, points out that the fuel consumption of a nuclear reaction is about 1 gramme of radium per day for an output of 1,000 kw. Consumption of uranium to propel the R.M.S. *Queen Elizabeth* from Southampton to New York would be 1¼ lbs. With uranium costing about £125,000 per pound, the picture does not look so bright, and Mr. Crowe thinks that it will be many years before atomic power will be used for ship propulsion.

New Radio Navigation Development

North British Chain of Decca Navigator Stations Opened

On June 7th last, the North British Chain of Decca Navigator stations was officially opened by Air Chief Marshal, Sir Frederick Bowhill, Master of the Honourable Company of Master Mariners. The opening ceremony was performed on board the "Royal Iris," specially chartered for the occasion by the Decca Navigator Company, Ltd., while the vessel cruised down the Mersey channel towards the Bar.

In the course of his remarks, Sir Frederick Bowhill said that the North British Chain gives additional coverage in the north and north-west of the United Kingdom and will be particularly valuable to shipping approaching the ports of Liverpool, Glasgow, Belfast and Dublin, and to deep sea vessels making landfall to the north and west of Ireland; Decca coverage in the North Sea is also extended.

Apart from its use as a general aid to navigation, the Decca Navigator had several special uses in the marine sphere — for example, for ships engaged in cable laying, buoy laying, salvage and survey work. The cable ship "Iris" was at the moment about to undertake cable work off Northern Ireland with the aid of the chain now opening. A number of fishing vessels were fitted with the Decca Navigator; it enabled them not only to navigate with exactitude to and from the fishing grounds and on them as well, but by use of the Navigator, fishermen could note by the Deccametre reading the spots where they had found a good haul and return there again without having to lay a marker buoy. The completion of the South-West British Chain, to which they could look forward towards the end of this year, would complete the original scheme for maritime coverage.

Sir Norman Guttery, Deputy Secretary, Ministry of Transport, said the accuracy of the Decca Navigator was truly amazing, and experience which was being gathered daily showed that it was a very dependable aid to navigation. Anything which made the calling of seamen safer deserved to be encouraged, and he hoped to see more and more of these chains opened so that ships could use them not only off the coasts of the United Kingdom, but also when approaching the main ports of the world.

THE NORTH BRITISH CHAIN OF STATIONS

The opening of this new chain of transmitting stations—the third to be established since commercial inception of the System in 1946—marks another stage in the progress of the Decca Navi-

New Radio Navigation Development—continued

gator since it emerged from its wartime role and was set up as an aid to marine and air navigation in North-West Europe.

The siting of the new Chain follows the accepted "star" pattern geographically, the Master station being sited at Kidsdale in Wigtownshire. The Red Slave station, so named because it generates the pattern of position-lines printed in red on charts, is at Clanrolla in Northern Ireland. The Green and Purple Slave stations are at Low Buston, Northumberland, and Neston, Cheshire, respectively.

The North British Chain extends the Decca Coverage to the north-western approaches and to Scottish waters and is important not only for coastal vessels but also for deep-sea shipping making the northern ports of the United Kingdom. Trawlers, too, will be able to derive benefit from the new Chain as they already do in large numbers from the English and Danish Stations.

THE GROWTH OF THE DECCA COVERAGE

The first commercial Chain of stations, in southern England, was completed in July, 1946, and a number of merchant ships was fitted with the Decca Navigator for trials by the Ministry of Transport. Following Ministry approval the first contracts were made in January, 1947, with shipowners for the hire of receivers, and in the same year the System was granted international approval at the New York International Meeting on Radio Aids to Marine Navigation. In August, 1948, the Lane Identification service was introduced on the English Chain, a technical refinement which extended the Decca facilities to ships and aircraft entering the coverage from places beyond the range of the stations. In October, 1948, the Danish Chain of stations was opened, extending the coverage from the North Sea to the Southern Baltic.

CURRENT EXPANSION

Three further Decca Chains—doubling the present coverage—are now in preparation.

The technical achievements in the air navigation field were key factors behind the West German Government's recent decision to erect a Decca Chain. The equipment is now being built by the Telefunken Company, Decca's German licensees, and is scheduled to be operating in September, 1951.

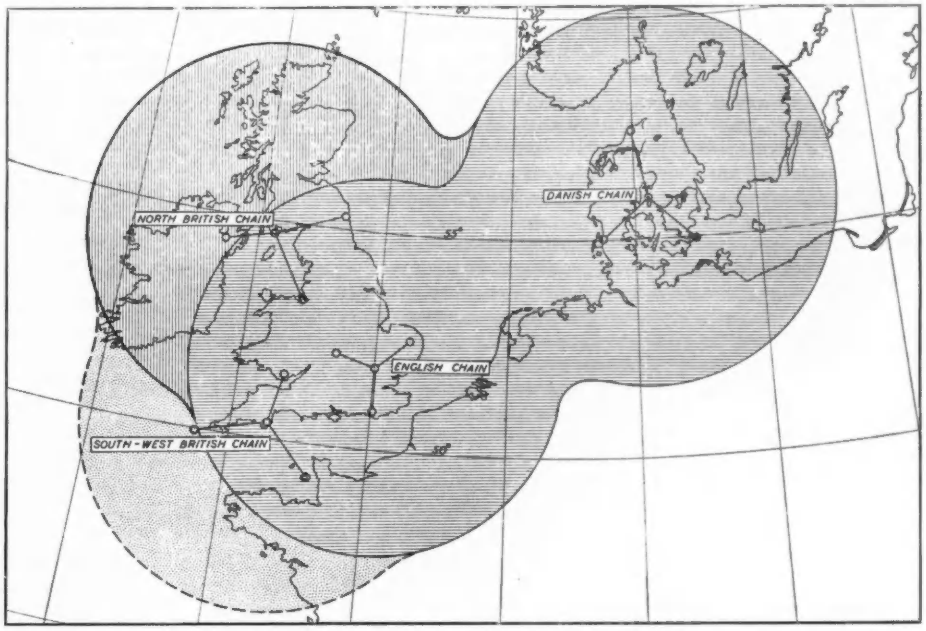
A similar Chain is being established by the Société Française Radio-Electrique for the French Government.

The complete coverage of the United Kingdom will be effected by the South-West British Chain, now under construction, extending the Decca facilities southward to the Bay of Biscay and enabling deep sea shipping from the south-west to make an accurate landfall under all conditions.

THE DECCA NAVIGATOR SYSTEM

Confusion sometimes exists between the functions of the Decca Navigator and Radar. They are, in fact, complementary aids to navigation. Radar detects objects and shows their direction and distance with respect to the user's set, giving the facility of collision-warning and enabling the ship's position to be fixed when known landmarks can be identified on the radar screen. The Decca Navigator does not "see" objects, but is a means of continuous position-fixing. It gives the user his position at all times and is employed throughout each voyage made within the service area. By enabling the desired course to be followed precisely, and independently of buoys or landmarks, the system effects marked savings in time and fuel in good weather as well as being invaluable in bad visibility.

The Decca Navigator has as its basis the "Chain" of ground transmitting stations. The three Decca Chains now established in Europe each comprise four stations, a central Master and three outlying Slaves. The stations send out continuous radio transmissions which interact to form a stationery radio pattern—akin to the stationery wave pattern which can be formed on the surface of water by the intermingling "rings" from two objects dropped in side by side. The lines making up this pattern remain permanently in known positions and can thus serve as navigational position-lines. They are depicted on standard marine charts as intersecting lattices, each line being numbered distinctively.



Map showing new cover from the North British Chain.

The Decca receiver carried on ships has clock-like dials which indicate continuously the numbers of the radio position-lines intersecting at the ship, so that to find one's position is simply a matter of reading-off two numbers from the instrument and finding the point on the chart where the indicated lines cut.

Book Review

United States Ports, by Dr. George Fox Mott, Ph.D., (Arco Publishing Co., Lexington Av., New York, U.S.A. Price $7.50).

The opening chapters of this book give a series of short essays dealing with port operation, geographical position as an economic factor; conditions affecting the flow of trade; modern facilities with regard to trade promotion; service control and management, etc.

The author does not lay claim to having made an exhaustive examination of all the conflicting economic and engineering theory or practice which has evolved in connection with port management and terminal operation, nor does he expound, from a layman's point of view, how ports should operate or what costs should obtain or what kinds of control should exist. He does, however, bring together in common-sense relationship those facts and opinions which help to clarify certain issues and explain certain similarities and differences between various ports.

The book is divided into four parts. The first contains the general conclusions of the survey; in the second special facts and information are presented, and reviewed. The third section is a comprehensive, port by port, analysis of thirty representative United States Ports, and part four briefly discusses other methods of transport, and gives a selected glossary of port terminology.

The production of this publication is unusual, as the pages are printed on one side only, and have the appearance of duplicated typewriting, which seems to imply that, in view of the new approach to the subject, the author is testing the potential demand.

The book is of special interest, because it is the first of its kind to be published, and although it deals specifically with American ports, the general conclusions and information cover a far wider field, so that it should prove of value to shipping interests throughout the world.

Port Development in the United Kingdom

Review of a Century of Enterprise and Achievement

By ROGER CHARLES

(continued from page 37)

LIVERPOOL

It is interesting to note a certain similarity in the reputed derivation of the names of the two leading ports of the United Kingdom.

The name London is said to be derived from the Celtic "Llyn-Din" meaning the "hill by the pool." The pool of London washed the shores of what was probably the first settlement and retains its name today.

A "pool" was also so significant a physical attribute to Liverpool's rise as a port as to be incorporated in its name.

The suggestion that the Norsemen named an early settlement on Merseyside "Hlithar Poler"—the "pool of the slopes"— is based more on fancy than fact but it is evident that the herring and salmon caught in the pool were amongst the first exports of this great port.

Early history is silent on the subject of Liverpool and it is not until 1207 when King John granted "letters patent" to the locality that the first mention of "Lyrpul" is made.

The first charter, as such, was granted to the town in 1229 by Henry III. This charter contained a clause which caused dissension for about 500 years. The contentious clause constituted the town a free borough, the burgesses a mercantile guild and precluded anyone not in this guild from transacting business in the borough without consent of the burgesses or their heirs. Those other than freemen were compelled to pay "town dues" on any goods brought into the town for sale and it was this levy which caused such acute controversy.

Edward III evidently regarded Liverpool as a Port of some importance for he ordered six ships to be provided and equipped there as part of his preparation for war against Scotland.

Then came the period of decline which has already been mentioned as a feature in some port histories. In 1544 Liverpool was included in a list of towns which had fallen into decay and later in the century, during the course of the famous litigation with the City of Chester, it was disclosed that twelve vessels belonged to the port, the largest of which was about 400 tons. Neighbouring Wallasey had three.

The trade curve took an upward trend about the beginning of the 17th century and by the early 18th century accommodation in the old harbour or pool was quite insufficient to deal with the volume of shipping much of which moored in the open roadsteads.

It was in 1709 that the Corporation began to seek the aid of the engineer to solve their problems. The first scheme projected was to widen and deepen the stream feeding the pool and to construct a canal. This idea was, however, rejected in favour of a proper dock and in the same year an Act of Parliament authorised its construction and constituted the Mayor, Bailiffs and Council its trustees. The dock was opened on 3rd August, 1715, but not completed until 1737.

Progress in dock construction was fairly rapid, the original dock was enlarged, Salthouse Dock opened in 1753 and in 1762 George's Dock was authorised to be built on a site between James Street and Chapel Street.

The slave trade, of course, brought considerable revenue to the port and when that trade was abolished in 1807 the protests of the Liverpool Town Council were understandable but the loss of business inevitable.

Improved inland communications by the development of the canal system during the second half of the century did much to restore the trade of the port and the rapid increase in the output of the manufacturing towns of Lancashire and Yorkshire, the proximity to which made Liverpool the natural outlet, resulted in a rapid expansion of business.

By 1825 the total area of dock accommodation in the port exceeded 45 acres. The George's dock had been enlarged and the King's, Queen's, Union and Prince's docks built. During the next few years, however, the growth of the port was even more remarkable, for the area of the dock estate was increased to 150 acres by the addition of the Canning, Clarence, Brunswick, Waterloo and Victoria, Trafalgar, Coburg, Toxteth, Albert, Salisbury, Collingwood, Stanley, Nelson, Bramley-Moore, Wellington and Wellington half-tide, Sandon and Huskisson docks.

As this review has already shown, the building of docks entailing large capital expenditure was the result of irresistible pressure of the increase of traffic; the termination of the East India Company's monopoly in the Indian trade in 1813 and the end of the American War of Independence, together with the consequent opening of trade with China were great factors in the development of Liverpool's prosperity.

Whereas the development of inland water transport during the last half of the 18th century helped Liverpool to recover from a bad period, the advent of steamships and railways early in the 19th century enabled the port to go from strength to strength and the demand for further dock accommodation attracted the attentions of private dock promoters.

The Harrington Dock Company was the first of these and had been formed to build warehouses and docks between Herculaneum Pottery and Brunswick Dock but after spending £50,000 in preparing the ground and in the construction of two small inlets for river craft its undertaking was purchased by the Dock Committee of the Council in 1843 for over a quarter of a million pounds.

The second and, so far as can be ascertained, the last attempt to provide dock accommodation by a private company was made by the Birkenhead Dock Company who, under Parliamentary powers, built the Morpeth and Egerton Docks which were opened in 1847 but the alert Corporation soon acquired this challenge to municipal dock administration.

Such then is the prologue, so to speak, of the romance of Liverpool's port, and now, for the purpose of this Festival review, the curtain rises on the main action of the play.

In 1851 an important change was made in the constitution of the Dock Committee, it being ordered that it should henceforth consist of 24 members, twelve to be nominated by the Council and twelve elected by the dock ratepayers; it was not, however, until six years later that the modern port can be said to have been inaugurated.

MERSEY DOCKS AND HARBOUR BOARD FORMED.

The Mersey Docks and Harbour Board, a body corporate with a perpetual succession and a common seal was constituted by an Act of Parliament in 1857. The first Board, which first met on 5th January, 1858, under the chairmanship of Mr. Charles Turner, consisted of 21 members, eighteen of which were "elected members" and three "nominee members."

The new Board soon gave evidence of its intention to bring Liverpool into line with existing requirements and in 1859 the Canada Dock was opened especially for the timber trade, the volume of which had exceeded the capacity of the Brunswick Dock. Five years later the Herculaneum Dock and two graving docks were built at the south end of the dock estate and in 1867 the Waterloo Dock was constructed including large warehouse accommodation.

The overseas trade of Britain and the size of the ships engaged in that trade were still increasing, and a further Act of Parliament was obtained in 1873 to construct new docks at each end of the estate, the authorized expenditure being no less than £4,100,000. As a result the Brocklebank, the Langton with one branch, and the Alexandra with three branches were opened in 1881, the Prince and Princess of Wales performing the opening ceremonies at the Langton and Alexandra docks respectively.

Port Development in the United Kingdom—continued

In 1884 the programme at the north end of the estate authorised by the Act of 1873 was completed by the opening of the Hornby dock. Meantime developments at the south end were taking shape. The Herculaneum dock was enlarged to provide additional accommodation for the coal trade, and a branch dock and new graving dock added. The opening of the Harrington and Toxteth docks in 1883 and 1888 respectively were further evidences of the Harbour Board's enterprise.

Still the development of naval architecture exerted pressure on the administration of the Port of Liverpool for great advances had been made in the beam and draught of new vessels coming into service.

So the story continues inexorably, new docks were built and existing ones enlarged but in 1907 the Board were able to pay attention to the domestic requirements of their large organisation and their famous Head Offices, which form so familiar a part of Liverpool's skyline flanked by the Cunard building and the Royal Liver Friendly Society's tall structure, were opened.

Port of Liverpool. Aerial view of Gladstone, Hornby and Alexandra Docks, and River Entrance.

The years immediately preceding the first World War saw the launching of a further large extension scheme. The Act obtained in 1906 provided for the construction of a group of docks consisting of a large vestibule dock with branch docks access to which was by way of a large new entrance lock and connected with the existing North docks by means of a lock 90 feet wide. The Gladstone Graving Dock—one of the largest dry docks in Europe—was constructed at a cost of nearly £500,000 and was opened on 11th July, 1913, by King George V.

The war called a halt to further development and it was not until the 19th July, 1927, that the Gladstone Dock and Branch Docks were opened.

ELECTRIFICATION.

Scientific developments in the last half of the century under review appreciably altered methods of dock working, for in 1925 a scheme for the electrification of the Northern and Southern portion of the dock estate was completed. The Electricity Board supplies electrical energy at high pressure to sub-stations provided by the Board from which it is distributed at medium and low pressure for power and lighting purposes respectively. Quite apart from the wiring for the sheds, the main cables laid in connection with the northern scheme between the Sandon and Gladstone docks are over 40 miles in length while on the southern scheme about 41 miles of cable were laid between the Canning and the Herculaneum docks. The site of the former Clarence Dock was used to build a large electrical power station which was designed to supply a wide area in Lancashire and Cheshire.

The development of the importation of bulk petrol naturally affected the appearance of the port and the large installations at Dingle and elsewhere are a distinctive feature of Merseyside. Most of the petroleum storage tanks belong to various oil companies and are erected on land leased to them by the Harbour Board, but the Board has its own installation on land south of the Herculaneum dock.

BIRKENHEAD DOCKS.

It must not be forgotten that the domain of the Mersey Docks and Harbour Board extends over both banks of the river and the acquisition by the Board in 1857 of the Birkenhead Dock Estate undoubtedly brought great advantage to Birkenhead while increasing the responsibilities of the Harbour Board. On this side of the river the programme of expansion was continued. The extensions of the Morpeth Dock, the Low Water Basin and Alfred Dock and Graving Dock in the rear, were undertaken. The Great Float was completed and the water admitted in November, 1860. The Low Water Basin was subsequently converted into a wet dock which, as altered, now forms the Wallasey dock. The Birkenhead system completed by the opening of the Bidston dock in 1933 now comprises, in addition, the West Float with its three small basins and three graving docks, the East Float with the Vittoria Dock inset, the Morpeth dock and its branch dock the Egerton dock,

Port Development in the United Kingdom—continued

the Wallasey dock and the Alfred dock which maintains connection between these docks and the Mersey. Originally these docks were crossed by hydraulic swing bridges at five important positions but electrically operated bridges of the rolling type suitable for modern wheel loads of both road and rail vehicles have been substituted. An extensive system of railway lines connect nearly all the Birkenhead quays with the main systems of British Railways who have large goods depots adjoining the docks.

The limits imposed by such a review as this, must of necessity, exclude discussion of many meritorious phases of the development of this world famous port, but a few principal features must be mentioned, the great Gladstone Graving dock, 1,050-ft. long and 120-ft. wide, with the 50-ton electric quayside travelling crane, for example. The Gladstone dock itself is of interesting layout. The great three-storey sheds occupying the full lengths of the two branches of the dock are set close to the quayside. In consequence it has been necessary to rig most of the cranes on the roofs of these substantial sheds. These cranes are electrically driven and about two-thirds are of 3-ton capacity and the remainder 20 cwts. Hornby dock, used largely for the handling of timber, is also equipped with five roof cranes but these are hydraulically driven and are of 30 cwts capacity.

At the Canada Branch Dock No. 3 there are a moveable hydraulic coaling hoist and a moveable coaling crane, each capable of shipping end-door wagons weighing up to 30 tons and 22½ tons gross respectively, at a rate of 300 tons per hour. The coaling hoist is fitted with a special apparatus for dealing with washed slack, thus obviating difficulties in discharging this material from the wagons.

The Landing Stage is, of course, well known. After various additions and vicissitudes including total destruction by fire in 1874 it is now nearly half a mile long.

Over 450 cranes are used in the port ranging from 20 cwt. to 87 tons capacity of which over 150 are mobile types. Seven floating derricks are available for heavy lifts from the "Titan" with a capacity of 25 tons to the "Mammoth" which can lift up to 200 tons. There are also about 1,100 petrol and electric trucks for use in the Port.

RADAR DEVELOPMENTS.

Of all the developments in the Port of Liverpool, perhaps the one which has attracted most general attention is the radar station situated at the north-west corner of the Gladstone Dock. The aerial is mounted on a conspicuous white concrete tower 80 feet in height and the top of the scanner is approximately 99 feet above high water spring tides. The radar coverage extends seaward over Liverpool Bay, for a radius of 20 miles and in the Mersey as far south as New Ferry. A continuous R/T watch is maintained and portable R/T sets for communication with the radar station are boarded with pilots at Point Lynas or the Bar. The first year of operation of the port radar station has shown that it is a valuable addition to the facilities of the port, 230 vessels of a gross tonnage of 1,334,328 tons having made use of radar assistance during this period.

BRISTOL

Bristol's geographical position together with its long, and often romantic, history invariably suggests the golden glory of the setting sun. The sunshine it enjoys is well shown in the excellent colour film recently made of the city and port which, however, clearly demonstrates that the sun of Bristol's achievement is by no means on the point of setting.

The two main causes of the Port's early rise to greatness were its natural harbour and its situation on the Bristol Channel, 100 miles from the open sea, where it was well out of reach of marauding pirates and thus able to offer a safe haven to legitimate traders.

Bristol enjoyed a considerable trade with Ireland and was the chief port in the west of England when Henry II gave the town its first charter in 1171.

In the 18th century the slave trade to the West Indies brought considerable affluence to the port, for in exchange for these human exports West Indian sugar and rum were the principal imports. It is recorded that there were twenty sugar refineries existing in Bristol in 1753 which gives a clear indication of the importance of West Indian business to the Port.

The abolition of the slave trade allied the ports of Liverpool and Bristol in a vociferous but unavailing protest.

Primitive riverside quays were a feature of the accommodation provided at several ports for the discharging and loading of cargoes, but the Mayor and Corporation of Bristol showed great enterprise as early as the 13th century, when they constructed a quay after diverting the river Frome into a new channel. It was at this period that a stone bridge was built over the Avon connecting old Bristol on the north bank with Redcliff to form a corporate City of Bristol.

This 13th century quay was destined to play a great part in history for John Cabot sailed from it in the *Matthew* in 1497 on his voyage of discovery to North America. Indeed many a significant voyage to destinations unknown started from this point, including that of the *Henrietta Maria* in 1631 with Captain Thomas James, a Bristolian, in the search for the North-West Passage.

The Society of Merchant Venturers was incorporated at Bristol by Edward VI in 1552, and became intimately concerned with the shipping business of the town, and about one hundred years later obtained a lease of the dues for anchorage, wharfage and plankage for a period of ninety years, on payment of almost a nominal rental, but with an obligation to build a new quay adjoining the old one. Later, the increase of trade made it necessary for a further extension to be made.

THE FIRST DOCK.

Common to most ports at this time were the problems presented by the relentless pressure of increasing trade and the inroads of pilferage. In Bristol, as elsewhere, men turned to closed docks for the solution of both problems. Joshua Franklyn, at the head of a group of merchants, decided to build a dock at Sea Mills three miles down river from Bristol. The dock was opened in 1713 and privateers, whaling ships and vessels with general cargoes used its quays. Lighterage was the order of that far off day, for the goods had to be discharged overside into craft for transference to City warehouses. The dock, however, proved unpopular and it was abandoned.

The main business of the port showed no decline however, and the Corporation constructed two new quays, and in 1764 the Society of Merchant Venturers undertook new obligations to extend the facilities of the port, this at the time when Bristol's trade exceeded that of Liverpool.

At the beginning of the 19th century a scheme propounded by Mr. William Jessop to meet the strong challenge of Liverpool was approved by the Corporation and the Merchant Venturers.

Dams were constructed across the Avon at Totterdown, Rownham and Netham turning a part of the Avon into a dock, or floating harbour. At Rownham two entrance locks with the Cumberland Basin gave access to the dock and another entrance and the Bathhurst Basin were constructed midway between Totterdown and Rownham on the new course of the River. The new works were first used in 1809 but proved more costly than estimated, with the result that the necessarily high dues levied by the Bristol Dock Company, the originators of the scheme, called forth numerous and persistent complaints. In spite of at least two reductions in charges, public opinion was not mollified, and the Free Port Association was formed with the object of "freeing the Port of Bristol from all charges on goods and shipping inwards and outwards, except such trifling charges as may be necessary for the convenience of the port, if to be effected on just terms."

This was the immediate prologue to the main period under review, for as a result of the excitement roused by the controversy over the charges question, an Act of Parliament was obtained and, on 28th August, 1848, the undertaking of the Dock Company was transferred to the Town. The immediate result was wholesale reductions in the port dues, and the Free Port Association, in the knowledge of a job well done, wound up in 1850.

Whatever early ambitions might have been held by the Bristol Corporation, any major development of the Port was not possible in the years which followed, since the trade of the port suffered serious decline and it was not until 1865 that a Bill was promoted and passed, authorising the first large scale work in the port since it was taken over by the Corporation. This comprised the building of a new entrance lock into the Cumberland Basin, a new junction lock from the Basin into the Floating Harbour and the removal of points and other obstructions in the river from Cumber-

Port Development in the United Kingdom—continued

land Basin to and including Pheasant Quarry Point. A landing stage at the mouth of the Avon and a railway were included in this new scheme of development.

It was not long before the advantages of Avonmouth as a suitable place for dock construction were appreciated. Here private enterprise took a hand, and in 1877 Avonmouth Dock was opened by the Bristol Port and Channel Dock Company. Two years later another company opened a dock at Portishead.

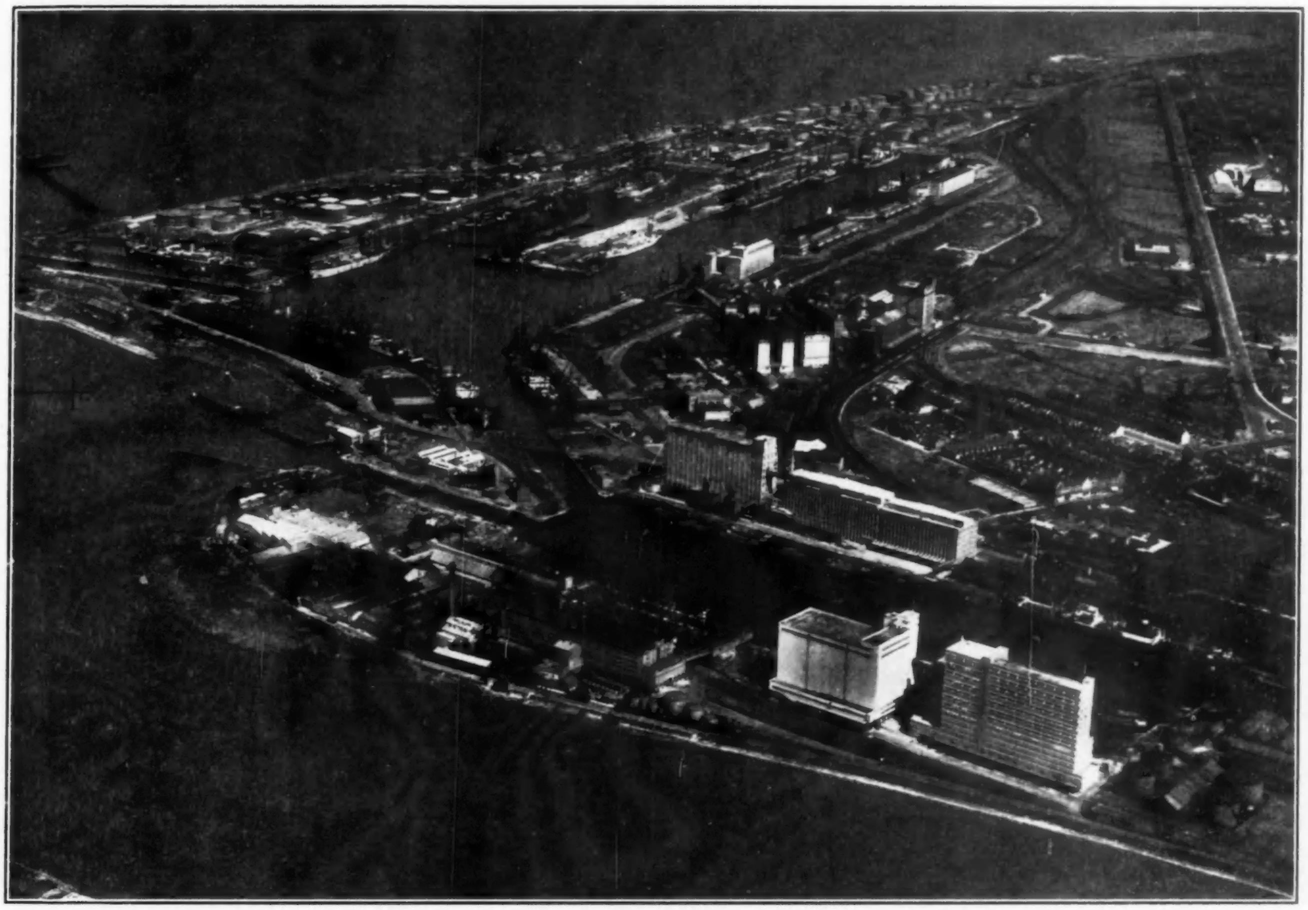
While many Bristolians thought that their port was now well-equipped to deal with any trade developing in the foreseeable future, the Corporation were watching the activities of Avonmouth and Portishead docks with some misgiving. The traffic in grain and provisions was steadily leaving the City docks for the privately owned undertakings and the Corporation decided that the competition was too fierce. In the consultations taking place as to remedies to meet the situation the question of forming a harbour Trust or Commission was widely discussed. But Bristol has always been noted for the civic pride of its citizens, and it is not therefore surprising to find that these two expedients were rejected in favour of the assumption of full port control by the municipality and, under an Act passed in 1884, the ownership of the dock undertakings of Avonmouth and Portishead passed to the Bristol Corporation.

This time no trade slump hampered the port development plans of the Corporation and the increasing size of ships indicated the scope of the new works to be undertaken.

In 1898 the Corporation constructed a new caisson at the Avonmouth Dock by means of which the accommodation was extended for vessels up to 485 feet in length. A new dock was also decided upon, and in 1908 the Royal Edward Dock was opened by King Edward VII. The entrance lock of this dock is 875 feet long, 100 feet wide and has a depth of water of 46 feet H.W.O.S.T. Equipped with modern appliances, including a passenger terminal, this dock can accommodate all but the very largest vessels and it also contains a graving dock of similar dimensions as the entrance lock and with a depth of 32 feet of water on the sill.

The port prospered and, although the first world war prevented further development, as soon as it was over the Royal Edward Dock was enlarged by the construction of the Western Arm for the accommodation of oil tankers. As an indication of the development of the oil trade of the Port it should be mentioned that in 1900 this trade amounted to 50,000 tons but towards the end of the second world war importations had reached nearly five million tons and the installations on the Dock Estate occupied over 120 acres to accommodate what had then become the principal trade of the port.

In 1928 the Eastern Arm of the Royal Edward Dock was opened for traffic and later was extended and especially equipped to deal with grain and a wide variety of general cargo.



Port of Bristol. Aerial view of the Royal Edward and Avonmouth Docks.

Thoughout their undertaking the Bristol Corporation carried out improvements including rebuilding transit sheds, building new wharves and equipping the whole port with mechanical appliances for the rapid handling of cargo.

The administration of the port including the conservancy and lighting of the river and the pilotage is vested in a Committee of the Corporation acting under the title of "The Port of Bristol Authority." All ships' berths, transit sheds, warehouses, granaries, cold stores and tenants' premises are directly served by the Port Authority's railway lines which connect with the sidings where traffic is exchanged with the main-line railways.

It has been the experience of more than one port that the development of road transport has made the problem of road access an acute one. It was so in London, where before the second world war the great Silvertown Way was constructed to facilitate road transport to the Royal Docks system. In Bristol a magnificent roadway, known as the "Portway," 5¼ miles long and for the

Port Development in the United Kingdom—*continued*

major part 100 feet wide, connects the Avonmouth docks with the centre of the city. The City docks are, of course, in the heart of Bristol and masts and funnels of ships intermingle with the City's spires to form a distinctive sky line. Vessels up to a length of 332 feet b.p. can berth in the City docks.

Communications have been modernised by the provision of a V.H.F. radio-telephone system, which links the Haven Master's Office to the pilot cutter on the Breaksea Pilotage Station.

Canals play their part in the transport of goods and British Waterways have vessels trading daily to the Port taking import cargo northward and returning with manufactured goods from the Midlands.

MECHANISATION.

The mechanisation of the port has kept pace with modern needs. The essential crane, the basis of all dock working, is there in ample numbers ranging from 30 cwt. to 10 tons capacity mostly on the quays but some, as in the case of Liverpool, mounted on the shed roofs. The usual dockside and shed equipment e.g. run-about trucks, tiering trucks, mobile cranes, pilers, conveyors, cargo lifts, shoots, spiral gravity roller runways etc., is provided. For timber working special long-jibbed mobile cranes have been installed and in view of the open nature of the storage grounds a Ross Straddle carrier fitted with a 72 h.p. engine and capable of conveying a load of 6½ tons from the discharging berth to the piling ground is proving most useful. These straddle carriers resemble a large four-wheeled tractor with the driving seat perched over the cargo space. They are fascinating to watch as they straddle their load, pick it up and, quite speedily, take it away to the required point.

THE GRAIN TRADE.

Bristol has long held an important position in the grain trade and in modern times the normal annual imports amount to about one million tons per annum. The reception and distribution of this large tonnage has called for equipment of a specialised character.

The Port Authority own four silo granaries at Avonmouth having a storage capacity of 62,000 tons. Both floating and fixed pneumatic and bucket elevators are provided to handle grain in bulk but the focal point of the system is the Transit Granary. Built on the silo principle this granary has a capacity of 12,000 tons and is designed to receive grain at an accelerated speed of discharge direct from the vessel by means of fixed and floating elevators and conveyor bands to road, rail or craft. Grain for storage in granaries Nos. 1, 2 and 4 is transported there by conveyor bands. Delivery of grain in bulk from the granaries to craft is effected through five travelling automatic weighers operating beneath the silos in the west wing of the Transit Granary. These weighers deliver on to telescopic barge-loading band conveyors extending over the quay and beyond the edge of the wharf. There is also a high-level shoot and a quay belt to facilitate delivery to large coasters and barges. This extensive system involves the use of nearly eighty electric motors with conveyor bands extending to upwards of seven miles in length.

Green and dried fruit, bananas, tobacco, refrigerated produce, cocoa, sugar, molasses, animal feeding stuffs, wine and many other commodities feature in the trade of this west country port which has made a worthy contribution to the national achievements being celebrated in this Festival year.

THE CLYDE PORTS

Many years ago M. Simonin, a leading French engineer, wrote: "Nowhere as at Glasgow is there revealed in such luminous traits all that can be done by the efforts of man, combined with patience, energy, courage, and perseverance, to assist Nature, and if necessary to correct her. To widen and deepen a river previously rebellious against carrying boats; to turn it into a great maritime canal; to bring the waters where it was necessary to bring the largest ships; and, finally, to gather a population of 750,000 inhabitants, all devoted to commerce and industry, upon a spot where only yesterday there was but a modest little town almost destitute of every species of traffic—such is the miracle which in less than a century men have performed at Glasgow."

If today we feel that the citizens of the 19th century were too prone to ascribe to the miraculous the intelligent and energetic use of natural forces and resources, at least we must give credit to the robust dwellers on Clydeside, now much more numerous than in M. Simonin's day, for their initiative in constructing the Clyde Ports.

The Clyde was, originally, a shallow, tortuous river with many banks, channels and islands and it was due to considerable expenditure of money, energy, enterprise and perseverance that it has been converted into the present fine ocean terminal.

Six centuries of the Christian era were almost completed before Glasgow's name was written on the pages of history; then Saint Kentigern, also known as Saint Mungo, founded a bishopric on the banks of the Molendinar stream. The little settlement clustering round this ecclesiastical centre was about eighteen miles above the deep channel, thus the river, not being navigable, played no part in the development of the market town, and the nearest port was Irvine, forty miles away on the Ayrshire coast.

In 1566 the first attempt was made to obtain direct access to the sea by means of the Clyde, but the efforts to cut a navigable channel through to the Dumbuck Shoal proved unavailing.

Charles I granted the City a charter in 1636 which included powers to improve the navigation of the Clyde from Glasgow to the Cloch, about 30 miles, and to levy dues, but little was done under these powers.

In 1658 the Glasgow magistrates tried to buy land at Dumbarton for the purpose of making a harbour, but the local people would have nothing to do with the scheme. Ten years later, however, thirteen acres were bought on the south bank of the river opposite Dumbarton, and Port Glasgow was established, including the first graving dock.

The trade then was small but a new avenue of endeavour was shortly to be opened to the enterprising Clydesiders. In 1707 came the union of England and Scotland, and the Scots, who had previously been excluded from British colonial trade, were now able to deal with the American colonies and secured a large share of the sugar and tobacco business. The American War of Independence, which began in 1775, interrupted the Transatlantic trade but industrial development, consequent upon the working of the local deposits of coal and ironstone, had obtained a firm foothold to the benefit of Port Glasgow. Nevertheless goods still had to be lightered up to the City from the lower reaches and the improvement of navigation remained a thorny problem.

John Smeaton, the well-known engineer, was the first to produce a definite but unwelcome scheme of river improvement and it was not until 1773 that any action was taken following an Act of Parliament obtained in 1770. The basis of the new scheme, the idea of John Golborne of Chester, was the contraction of the river by means of jetties coupled with dredging and to let the natural scour do the rest. When the Act was passed, the Clyde could be crossed on foot at Dumbuck Ford twelve miles below Glasgow, and the "Comet," the Clyde's first steamer, grounded although drawing only four feet of water; in 1781 the depth of the channel at Dumbuck was fourteen feet at low water. John Golborne's scheme was fully vindicated and it is said that he was given £1,500 more than his contract price since his efforts exceeded all expectations. Thus the quay built at the Broomielaw, Port Glasgow, in 1688, which was of little use owing to the shallow water alongside, became available to any ship then likely to seek a berth there.

John Rennie and Thomas Telford were two other famous engineers who assisted in the development of the Clyde.

Up to 1818 no vessel in the foreign trade had ever come up to Glasgow, consequently most of the goods handled were coastwise or of local origin. The exceptions were timber, sugar and tobacco, the importation of the latter commodity amounting to more than 50 per cent. of the imports of the United Kingdom.

In 1809 the powers of the City Council were defined and as Trustees they took over the responsibility of maintaining and improving the harbour and river. In 1825 additional powers for deepening the river and other works were obtained. In 1858 the administration of the Port passed from the City Council to a reconstituted statutory body known as the Clyde Trustees and consisting of nine members elected by dues payers, two selected by the Chamber of Commerce, Merchants' House and Traders' House respectively and ten Town Councillors.

It will thus be seen that during the period prior to the Great Exhibition of 1851 the Clydesiders had been involved in adapting unwilling nature to serve their needs for a port.

Port Development in the United Kingdom—continued

DOCK CONSTRUCTION.

The maximum tidal range of the Clyde is only about twelve feet and a system of closed docks was unnecessary. Consequently the so-called docks on the banks of the Clyde are in reality a series of open tidal basins and wharves accessible to shipping at all states of the tide.

In forming an assessment of the measure of achievement of the Clyde Trustees it should be borne in mind that there is no uniformity in the geological strata over comparatively large areas of the Clyde valley; running sand, alluvial silt, gravel, boulder clay and basaltic rock being some of the materials found there. As a result of this there is, naturally, a great diversity in the structure and components of the dock walls.

The need for docks had been felt so early as 1840 and in that year the building of the Kingston Dock with a water area of five acres had been authorised. It was not, however, opened until 1867 but it nevertheless marked an epoch in the development of the Port. The total imports and exports at that time were 1,600,000 tons. Kingston Dock rapidly became the terminal for wooden barques which loaded plant for the sugar plantations of the West Indies, and more modern ships, cargo for Sydney. Ice from Norway was also handled in this dock which was reconstructed in 1916.

In 1877 the Queen's Dock was opened, being brought into full use in 1880, and the Prince's Dock followed in 1897. Then came the Rothesay Dock (Clydebank) in 1907 with the then exceptional feature of full electrical equipment.

Some measure of the progress of the development of the Port can be gauged from the fact that slightly more than 100 years ago the total length of quays and wharves was about ¾ mile whereas today it is over twelve miles. The quayage, comprising tidal riverside and dock berths, is always ready for the reception of ships of every class.

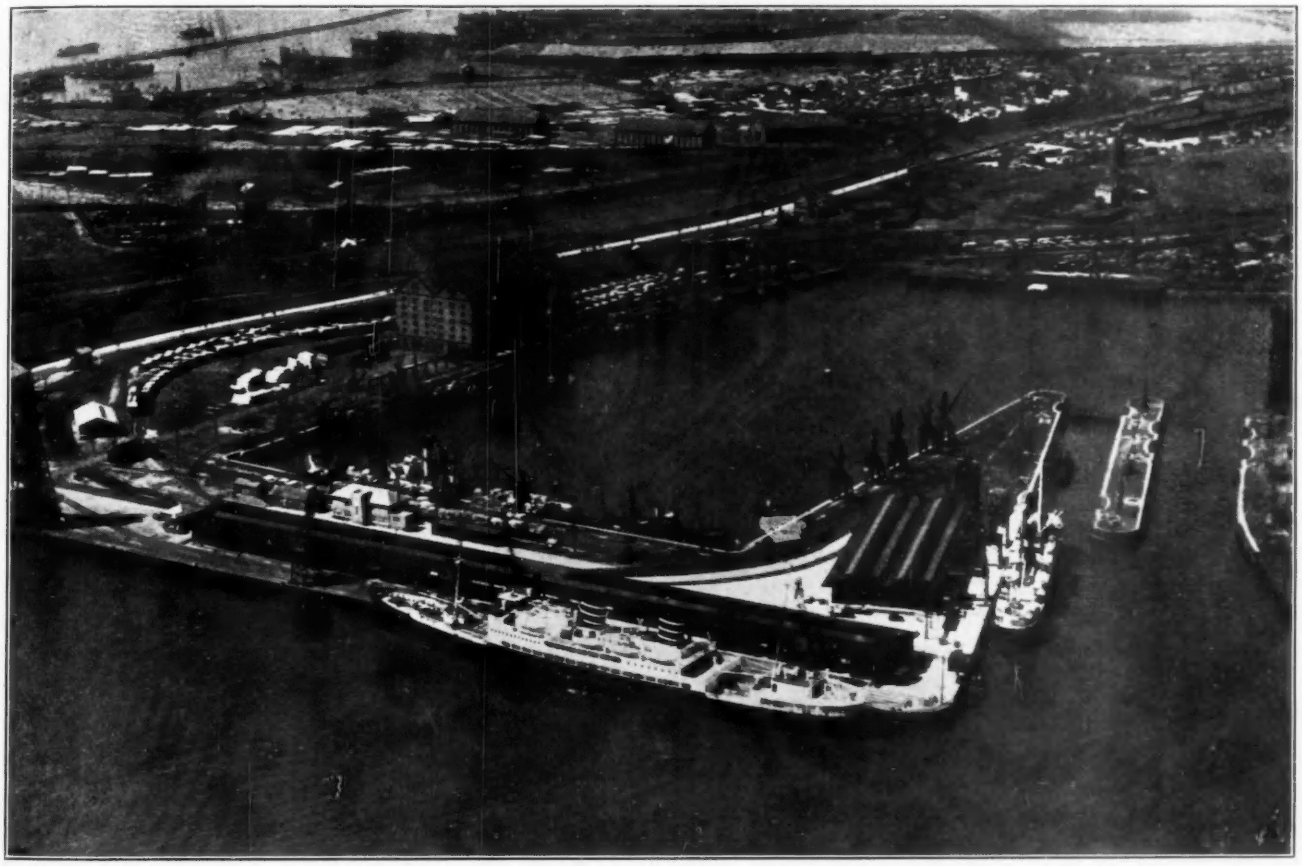
The general berthing pattern in the Port of Glasgow is for the coastwise traffic to occupy berths at the eastern end of the Port and the size of the ships to increase as the river flows westward. Many quays and sheds abut on to the streets of the City. Further down, the Queen's Dock occupies about 35 acres on the north bank and on the other side of the river is the Prince's Dock of similar area. Deep water berths with transit sheds and full equipment for dealing with general cargo adjoin these docks and extend to the westward of them. Still further down is the latest dock to be built; the King George V. Dock opened in 1931 with a water area of twenty acres and a depth at high water of 44 feet.

Work on the Port still continues and the reconstruction of Plantation Quay across the Finnieston Ferry recess is the subject of an informative article by Mr. A. J. Carmichael in the April issue of this Journal.

In 1944 the Minister of Transport appointed a Committee "to enquire into the present arrangements for the provision and administration of navigational facilities and of docks and harbours of the River and Forth of Clyde and the locks leading from them, and to report what modifications, if any, in those arrangements are desirable for the promotion of the trade of the estuary and the public interest." Lord Cooper, Sir Robert Letch and Mr. Robert Taylor, who formed this Committee, reported that they considered that the time was ripe for bringing the river and estuary as far down as the Cumbraes under the full control of a single unified authority.

The matter has been pursued under the provisions of the Transport Act 1947 and the proposals made by the Docks and Inland Waterways Executive of the British Transport Commission have called forth the resolute opposition of the Clyde Navigation Trustees.

Without expressing an opinion on the merits of the unification proposals it can at least be said that the present Trustees have enough evidence to show that their forerunners could never be accused of lack of enterprise and determination to make the Port of Glasgow into a first-class ship terminal.



Port of Newcastle. Aerial view of Tyne Commission Quay and Tyne Commission Quay Extension.

(to be continued)

Harbour Control Radar

Exhibit at the South Bank Exhibition

In previous issues of the "Dock & Harbour Authority," articles dealing with the work of the Wallasey Corporation Ferries have presented in detail the many exacting problems which at one time faced this vital concern in maintaining its cross-river service during fog; its ultimate decision to adopt shore-based radar supervision of its vessels, and the highly successful results obtained from this form of assisted navigation under the most adverse weather conditions.

The first installation—manufactured and fitted by Cossor Radar Ltd. in 1947—had a single 9-in. diameter screen or P.P.I. (plan position indicator), but this equipment was superseded in July, 1949, by an up-to-date console having twin 15-in. diameter screens, considerably advanced in design and efficiency. This C.M.R. console did much to convince shipowners and port authorities of the possibilities of shore-to-ship radar, at that time largely experimental and concentrated in the Cossor installations at Douglas Harbour (Isle of Man), and the Tilbury-Gravesend ferry service.

The experience gained from the operation of these installations over a number of years has provided a thorough understanding of the special problems and requirements appertaining to shore-based radar and, as a result of this, Cossor Radar Ltd. have now developed a standard yet flexible equipment specifically designed to meet the varied requirements of ports and ferry services throughout the world.

Before describing in detail the latest type of C.M.R. harbour supervision radar which is now being demonstrated daily in the Transport and Communications Pavilion at the South Bank Exhibition—a development of that used with the Wallasey Corporation Ferries—it would be advisable to dwell briefly on the use of shipborne equipment from the standpoint of harbour navigation.

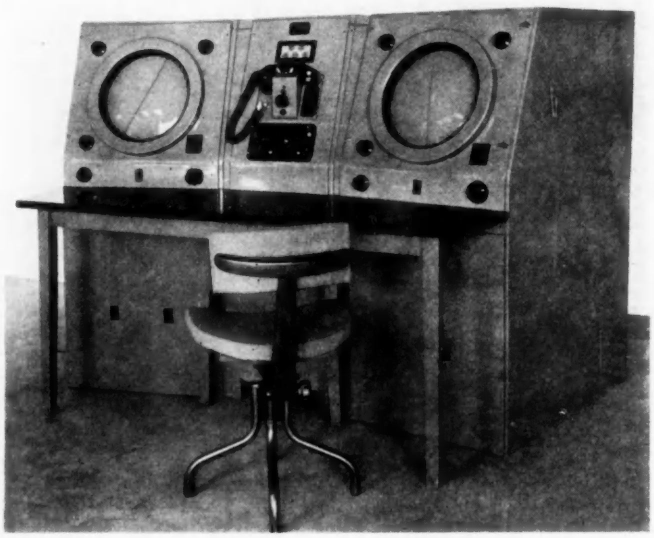
The necessity to keep the size and weight of shipborne radar as small as possible limits the degree of definition and the size of the display which it is possible to produce. The Marine Radar Performance Specification of 1948, issued by the Ministry of Transport, is a standard for shipborne equipment. It is, in fact, a compromise between the demands of the navigator for long-range indication of ships and land targets for use in avoiding collision, when making landfalls, and his need for assistance in close-range pilotage. Over and above this is the limit imposed by the space and electrical power available in a ship.

The vessel which is fitted with her own radar can go a long way towards getting herself into a number of harbours when visibility is poor, providing that the harbour entrance is simple and the density of moving shipping light. However, as the contortions of the channel become more complicated and the number of ships underway increases, the limitations of the equipment become more obvious. And this occurs just at the time the captain and pilot need to concentrate all their attention on the actual business of manœuvring.

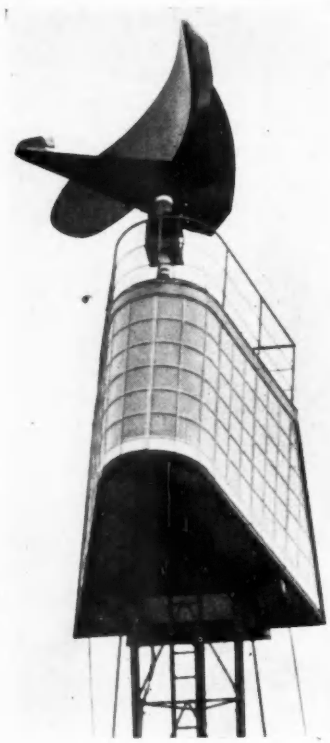
Thus it will be seen that the advantages of shore-based equipment of higher power and definition, and manned by an operator free of many of the worries attendant on a ship's master in difficult waters, are considerable. For this type of assistance to be effective, ships must be supplied with information of their position relative to obstacles in their path, whether stationary or moving. The accuracy of such information must be of a very high order.

The South Bank console, representing as it does standard shore-based radar equipment, fully demonstrates the efficiency of this form of supervision. Normally equipped with one or two display units—in this particular instance, as the accompanying photograph shows, there is a double display, each with a 15-in. diameter screen—the equipment is designed for the connection of any number of display units that may be necessary (for example) for the control system of the largest port. The required information is passed through multi-channel V.H.F. radio-telephone, shown on the central panel.

Each display unit has its own independent controls—brilliance, focus, gain, range, etc.—and in each case a special off-centring of the electrical centre of the tube, around which the time-base rotates, is possible. These centres—they represent the actual position of the equipment—can be off-set to any part of the screen, and with the usual shore-based radar station seaching in one direction only this means that the whole area of the screen, or screens, can be utilised for effective display. These electrical centres can be positioned quite independently; one tube normally centred, for instance, and the other off-set as required. Ranges from a minimum of 0.6 miles—giving ten inches to one mile—to a maximum of 15 miles at .5 miles to the inch, are possible. Special long ranges can be introduced as required. These ranges can be read accurately (in yards) to within 1% of the maximum range in use, by means of a moving scale indicator.



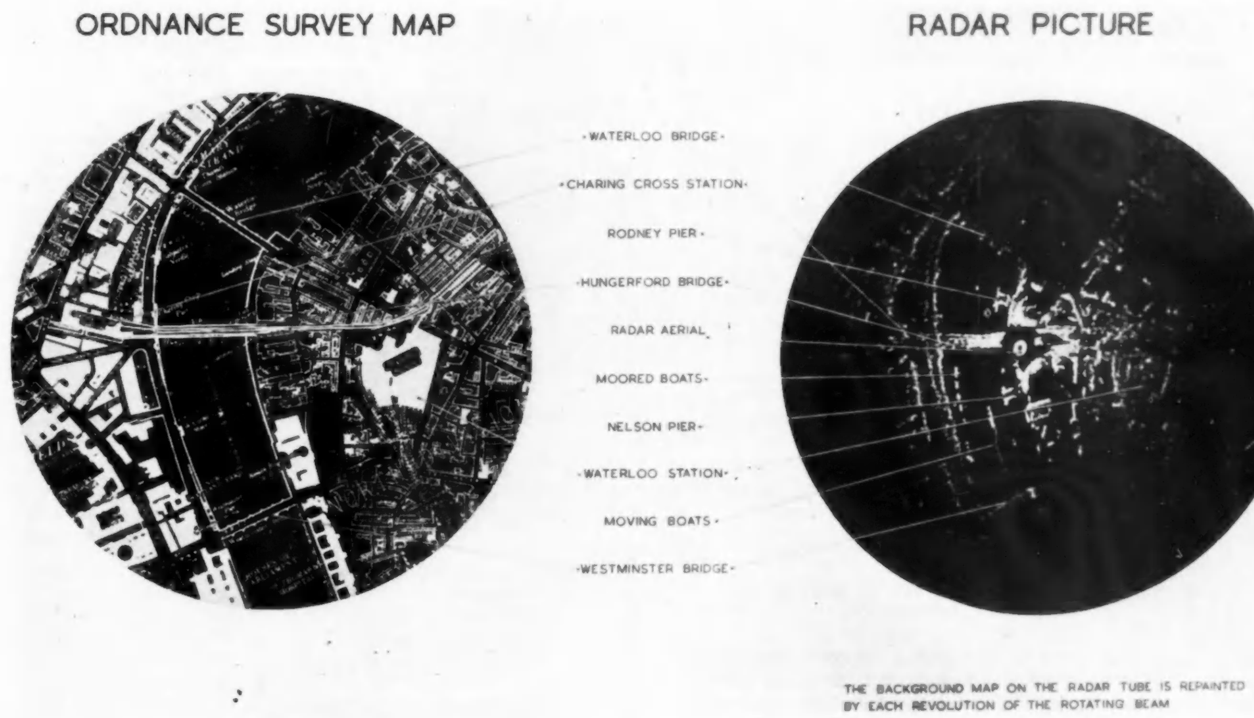
(Left)—The display console, showing two display units, with their 15-in. diameter screens slightly offset on either side of the central panel which is fitted with V.H.F. radio-telephone. The console has been designed for the addition of any number of such display units—with auxiliary equipment—as may be necessary to cover very large ports.



(Right)—The new type of scanner shown here has been developed from an entirely new process of plastic design. In the streamlined cabin beneath, is housed the main rack unit. It should be emphasised that the mast and cabin depicted have been designed to fit in with the exhibition layout, and are not standard in the radar equipment

The scanner, or aerial, consists of a section of a parabolic cylinder fed by a single horn, which is off-set below the main

Harbour Control Radar—continued



This photograph shows the radar picture of the River Thames contrasted with an inset of the same area from an Ordnance Survey map. Waterloo, Hungerford and Westminster Bridges are clearly seen, also moored vessels on the Thames. Ranges from a minimum of 0.6 miles to a maximum of 15 miles are available, although longer ranges can be introduced if required.

beam; this unit has been developed from an entirely new process of plastic design and has added considerably to the definition of echoes on the P.P.I. as well as reducing sidelobes to a minimum. A rotating gear is fitted and, together with the magslip unit, is in a watertight compartment. The motor drives the reflector at 20 r.p.m in winds up to 80 knots. The streamlined cabin immediately beneath the scanner contains the Main Rack unit, thereby utilising the shortest length of waveguide. Its maximum distance from the scanner should not normally exceed thirty feet.

The Main Rack contains the main electronic equipment of the console—including the transmitter/receiver—in racks, as its name implies, set one above the other. This cabinet measures 56¼-in. x 17¾-in. x 22½-in.

Great stress has been laid, during the design of this equipment, on the requirements for a very high degree of reliability and routine maintenance. The unit principle has been adopted both in the Main Rack and Display Consoles, and the equipment will operate fully when these units are in the withdrawn position.

National Harbours Board of Canada

Increase in Trade and Revenues for 1950

The following excerpts are taken from the fifteenth annual report of the Canadian National Harbours Board, covering the operations for the calendar year 1950, of the harbours of Halifax, Saint John, Chicoutimi, Quebec, Three Rivers, Montreal, Churchill and Vancouver, and the Government grain elevators at Prescott and Port Colborne.

SHIPPING AND CARGO TONNAGES

Vessel arrivals in 1950 numbered 46,154, the aggregate net registered tonnage being 37,115,589. The comparable figures for 1949 were 44,067 vessels, aggregating 34,723,963 net registered tons.

The aggregate cargo tonnage in 1950 at all harbours administered by the Board was 36,615,483, as compared with 33,713,796 in 1949. The increase over the previous year was 2,901,687 tons, or 8 per cent. The outstanding feature was an increase of 3,303,248, or 37 per cent., in foreign inward traffic. Foreign outward tonnage decreased by 1,636,289 tons, or 16 per cent. A reduction in the volume of grain exports was responsible for about 60 per cent. of the drop in export tonnage. Domestic traffic, both inward and outward, showed gains, the total being 1,234,728 tons greater than in 1949.

Of commodities moving in volume, petroleum and petroleum products showed the large increase of over 2,000,000 tons over the previous year. Substantial increases in total tonnages were also shown for bituminous coal, motor vehicles, lumber, pulpwood, manganese ores, anthracite coal, sugar and wheat flour. Grain showed a drop of nearly 1,200,000 tons, and miscellaneous general cargo items were lower.

OPERATING REVENUES AND EXPENDITURES

Operating revenues of all units administered by the Board amounted to $15,165,345, which is a record figure and compares with $14,072,697 in 1949. The increase was $1,092,648, or nearly 8 per cent. Wharves and piers produced about 11 per cent. more revenue than in the previous year. Other facilities showed moderate gains. Grain elevator earnings, notwithstanding the decrease in quantities handled, were slightly higher than in 1949, due to more storage.

Expenses of administration, operation and maintenance in 1950 were $8,675,006, as against $8,160,622 in 1949, an increase of $514,384, or 6 per cent. Outlay on maintenance of properties was $2,192,000, as compared with $2,064,000 in the previous year.

Operating income in 1950 showed a gain of $578,264, the comparable figures being $6,490,339 in 1950, as against $5,912,075 in 1949.

After taking into account debits and credits to income and charging interest and reserve for replacements, operations for 1950 resulted in a net income deficit of $787,650. This com-

National Harbours Board of Canada—*continued*

pares with a deficit of $1,493,517 in 1949. The deficit, therefore, decreased by $705,867.

CONSOLIDATED STATEMENT—SEVEN HARBOURS

The seven harbours administered by local commissioners prior to 1936—Halifax, Saint John, Chicoutimi, Quebec, Three Rivers, Montreal and Vancouver—had aggregate operating revenues in 1950 of $13,924,837, as compared with $13,066,488 in 1949. The increase was $858,349, or 7 per cent. Expenses of administration, operation and maintenance increased from $7,376,641 in 1949 to $7,648,490 in 1950, the difference being $271,849, or 4 per cent. Operating income increased from $5,689,847 in 1949 to $6,276,347 in 1950.

After taking into account income debits and credits and charging interest and reserve for replacements, a net income deficit of $1,002,755 was shown for these harbours in 1950, as compared with a deficit of $1,717,375 in the previous year.

During the period that these harbours have been under the administration of the Board, annual revenues have increased by $5,900,000, and operating expenses have risen by $3,200,000. The annual deficit position has shown an improvement of $4,800,000, due in part to the increase in operating income and in part to a reduction in interest rates on borrowed capital.

It is to be observed, however, as regards harbours in Eastern Canada, that had it not been for the comparatively high level of grain elevator earnings in the past two years, a deteriorating rather than an improving result would have been shown. In other words, earnings from other facilities have not kept pace with the higher costs of operation and maintenance.

PRESCOTT, PORT COLBORNE AND CHURCHILL

Consolidated income statement for the three Government facilities transferred to the Board for administration in 1937 —grain elevators at Prescott and Port Colborne and the harbour of Churchill—showed operating revenues of $1,240,508 in 1950, as compared with $1,006,209 in the previous year. Operating and maintenance expenses were $1,026,516 in 1950, as against $783,980 in 1949. The three units showed a surplus of $215,104 in 1950, slightly less than the surplus of $223,857 reported for the previous year. Both Prescott and Port Colborne showed increases in earnings, but these were offset by Churchill's greater deficit, which was due to periodic harbour dredging being required in 1950. The accounts for these facilities do not include charges for interest or reserve for replacements, other than a small amount for interest on capital expended since these units were transferred to the Board.

New Light Floats for Humber

Among the numerous types of craft which Messrs. Cook, Walton and Gemmell, Ltd., have recently delivered from their Beverley Shipyard, is a pair of Light Floats for the Humber Conservancy Board.

Those responsible for the design and construction have aimed at improved robustness and good compartmentation to give extra stability, so that the float will remain above water in the event of collision. The vessels have good riding qualities, and can be towed with ease. The design is such that the float will roll readily and so obtain the maximum effect from the pendulum bell strikers. Experience has shown that this feature also safeguards the floats against frequent damage, as, instead of resisting impact, they give easily, and in severe cases, roll upside down. From this position, they can be easily righted by parbuckling, and usually the only damage is to the light flashing mechanism due to the entry of water through the air intake.

As will be seen in the accompanying illustration, the floats are double-ended units, the aft end having a skeg reminiscent of that found in Thames barges. The mooring pipe, of normal lightship type is at the forward end. The hull, which is 40-ft. in length between perpendiculars, with a beam moulded of 16-ft., and a depth moulded of 5-ft. 9-in., is of all-welded steel with deep reversed angles forming floors.

Forward and aft there are buoyancy compartments, and the centre compartment houses the control equipment and gas bottles. The deck is flush plated and built so that water will not collect in pockets. The large W.T. hatch of rectangular shape gives access to the centre compartment, and manholes on raised coamings lead to the end compartments. A spherical buoy float is arranged in a cradle on the after deck to mark the position of a sunken float. It is automatically released as the float overturns. Four mooring and one towing bollards, of Humber Conservancy design are also fitted. The light itself has a focal point—17-ft. above the normal waterline and is mounted on a steel lattice structure with the name plate fastened on the side. At the base of this structure there is a bell operated by a carbon-dioxide gas hammer for use during foggy periods.

The whole of the light equipment has been supplied by Messrs. Gas Accumulator Company of Brentford, Middlesex, and is the same as that used on all the other floats and buoys in the Humber.* In addition, there is a lantern containing a cylindrical lens of about 100 mm. focal length and an open burner giving

*A short article entitled "Bells as an Aid to Marine Navigation" which described this type of apparatus appeared in the March 1950 issue of this Journal.

a flashing light, controlled by a complicated flashing mechanism. Sufficient gas is stored in cylinders in the float to operate the light for 12 months with a small reserve. Either single or multiple flashes can be given at a speed varying roughly from 30 flashes to three flashes per minute. Once set, the timing of the flashes is maintained with remarkable accuracy.

One of the new floats has now been in use for some time on the Ness station, which marks the entrance to the narrow shifting channel of the Upper Humber. The second is designed to relieve lightships and other floats during the time they are undergoing normal maintenance, and also when they have to be withdrawn as a result of collision or other emergency. Very soon after the float was taken over, the Spurn Lightship was hit by the Beverley built trawler, S.S. "Princess Elizabeth" and sustained damage which necessitated bringing it in for repair. The new float was put out on the station, which is some four miles out at sea, and successfully rode out the worst south-east gale of the winter.

Publication Received

Messrs. Chance Bros. Ltd., recently published a special Festival of Britain production, entitled **Mirror for Chance**, which is at one and the same time a life history of the Company and a survey of their present activities as glass makers and engineers. The book is not a catalogue or even a work demanding special technical knowledge on the reader's part. Rather, it is designed to convey to whoever may open it something of the scope and personality of the firm—to be, in fact, a mirror for Chance.